DESIGN CONCEPT OF SALAK HARVESTING TOOLS TO PREVENT INJURY RISK AND IMPROVE FARMER EFFICIENCY

UNDERGRADUATE THESIS

Submitted to the International Undergraduate Program in Industrial Engineering in Partial Fulfilment of Requirement for the Degree of Sarjana Teknik at the Faculty of Industrial Technology Universitas Islam Indonesia

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YOGYAKARTA
2026

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Yogyakarta, 14 August, 2026





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DEDICATION PAGE

This dedication is dedicated in full to my both parents, my brother, my whole family, and to myself. I would like to express my deepest gratitude to everyone involved in the process of writing this final project report. Thank you for taking the time, energy, and everything else to help the author complete the writing of this final project. May you always be granted ease, health, and a long life.

MOTTO

"Allah does not burden a soul beyond that it can bear. "

He gives me the strength to keep moving forward. Every sincere effort will surely bear sweet.

(QS. AL-BAQAROH:286)

PREFACE

Bismillahirrahmanirrahim
Assalamualaikum Warahmatullahi Wabarakatuh

All praise and gratitude be given to Allah Subhanahu Wa Ta'ala, who has bestowed His mercy, blessings, and guidance upon the author, enabling the author to complete this undergraduate thesis entitled "Design Concept of Salak Harvesting Tools to Prevent Injury Risk and Improve Farmer Efficiency." This thesis is prepared as one of the requirements for obtaining a Bachelor of Engineering degree in the Industrial Engineering Study Program, Faculty of Industrial Technology, Universitas Islam Indonesia.

In the process of completing this thesis, the author realizes that its completion could not have been achieved without the assistance, support, guidance, and prayers of various parties. Therefore, with sincere gratitude, the author would like to express appreciation to all those who have contributed their time, energy, thoughts, and support throughout the preparation of this thesis, particularly to:

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ABSTRACT

Salak, or snake fruit, is one of Indonesia's important horticultural commodities with high economic value. Practically, salak harvesting is commonly performed manually using conventional tools, which may cause thorn injuries, physical discomfort, and inefficient cutting movements. This study aims to develop an ergonomic salak harvesting tool that improves comfort, ease of cutting, safety, and reliability. The Axiomatic Design method was used to translate customer needs into Functional Requirements (FRs) and Design Parameters (DPs), resulting in four main Customer Attributes (CAs). The proposed design incorporates an ergonomic handle, trigger-operated anvil-type cutting mechanism, internal linkage, long-reach shaft, and integrated fruit holder, with anthropometric data applied to the handle dimensions. The FR and DP mapping produced a diagonal design matrix, indicating an uncoupled design that satisfies the Independence Axiom. Validation using the Marginal Homogeneity Test to determine whether the proposed salak harvesting tool design meets the customer attributes, the result showed that all values are greater than 0.05 with the detail 0.058 for CA1, 0.059 for CA2, 0.132 for CA3 and 0.221 for CA4. Wilcoxon Signed-Rank Test showed significant differences between the existing and proposed designs for all Customer Attributes, with values below 0.05 for Comfortable, Ease of Cutting, Safety, and Reliability. The usability evaluation obtained a SUS score of 75.75 (Grade B, Good), indicating an acceptable level of usability and user satisfaction. Overall, the proposed design provides an ergonomic harvesting solution with improved user perception based on the identified requirements.

Keywords: Ergonomic, Harvesting, Axiomatic Design, Anthropometry, Independence Axiom, Usability, SUS

TABLE OF CONTENT

AUTHENTICITY STATEMENT ..... **ii**
RESEARCH COMPLETION LETTER ..... **iii**
SUPERVISOR APPROVAL SHEET ..... **iv**
EXAMINERS' APPROVAL PAGE ..... **v**
DEDICATION PAGE ..... **vi**
MOTTO ..... **vii**
PREFACE ..... **viii**
ABSTRACT ..... **ix**
TABLE OF CONTENT ..... **x**
LIST OF TABLES ..... **xii**
LIST OF FIGURES ..... **xiii**
CHAPTER I INTRODUCTION **1**
1.1 Background 1
1.2 Problem Formulation 2
1.3 Research Objectives 2
1.4 Benefits of research 2
1.5 Research Limitations 3
CHAPTER II LITERATURE REVIEW **4**
2.1 Empirical Review 4
2.1.1 Axiomatic Design in Design Development 4
2.1.2 Ergonomic and Human Factor in Agricultural Tools 4
2.1.3 Development of Harvesting Tools 5
2.2 Theoretical Basis 7
2.2.1 Ergonomic 7
2.2.2 Product Design 7
2.2.3 Characteristics of Salak Fruit 8
CHAPTER III RESEARCH METHODOLOGY **9**
3.1 Research Object 9
3.2 Research sample and Population 9
3.3 Research Data Types 9
3.3.1 Primary Data 9
3.3.2 Secondary Data 10
3.4 Data Collecting Method 10
3.4.1 Observation Method 10
3.4.2 Interview Method 10
3.4.3 Direct Measurement 10
3.4.4 Literature Study 10
3.5 Research Instrument 11
3.5 Data Processing and Analysis Method 11
3.5.1 Axiomatic Design 11
3.5.2 Anthropometry 12
3.5.3 Usability Testing 13
3.5.4 Validity Test 14
3.5.5 Reliability Test 14
3.5.6 Uniformity Data Test 14
3.5.7 Normality Test 15
3.5.8 Adequacy Data Test 15

3.5.9 Marginal Homogeneity Test 16
3.5.10 Wilcoxon Signed-Rank Test 16
3.6 Research Flow 16
3.6.1 Preparation Step 17
3.6.2 Collecting Data 18
3.6.3 Processing Data 19
CHAPTER IV DATA COLLECTION AND PROCESSING 20
4.1 Data Collection 20
4.1.1 Respondent Characteristics 20
4.2 Data Processing 21
4.2.1 Customer Attributes Identification 21
4.2.2 Validity Test 21
4.2.3 Reliability Test 22
4.2.4 Adequacy Test 23
4.2.5 Anthropometry Data Processing 24
4.3 Axiomatic Design Mapping Process 27
4.4 Design Concept 32
4.4.1 Design based on Axiomatic mapping 32
4.4.2 Final Design Concept 34
4.5 Proposed Design Validation 35
4.5.1 Marginal Homogeneity Test 35
4.5.2 Wilcoxon Signed Rank Test 35
4.5.2 Usability (Satisfaction) 36
CHAPTER V DISCUSSION 38
5.1 Analysis of Customer Attributes 38
5.2 Analysis of Proposed Design 39
5.2.1 Analysis of Functional Requirements 39
5.2.2 Analysis of Design Parameters 39
5.3 Analysis of Proposed design validation 41
5.3.1 Marginal Homogeneity Test 41
5.3.2 Wilcoxon Signed Rank Test 41
5.3.3 Usability (Satisfaction) 42
CHAPTER VI CONCLUSION AND SUGGESTIONS 43
6.1 Conclusion 43
6.2 Suggestions 44
REFERENCES 45
APENDIX A-1

LIST OF TABLES

Table 2. 1 Research Gap 6
Table 4. 1 Respondent characteristics 20
Table 4. 2 CA Identifications 21
Table 4. 3 Result of Validity Test 22
Table 4. 4 Result of Reliability Test 23
Table 4. 5 Uniformity Testing Anthropometric Data 25
Table 4. 6 Adequacy Testing Anthropometric Data 26
Table 4.7 Percentile Data 27
Table 4. 8 Mapping result for CA1 28
Table 4. 9 Mapping result for CA2 29
Table 4. 10 Mapping result for CA3 30
Table 4. 11 Mapping result for CA4 31
Table 4. 12 Result of Marginal Homogeneity Test 35
Table 4. 13 Result of Wilxocon Test 36
Table 4. 14 Result of SUS Test 36

LIST OF FIGURES

Figure 3.1 Four Domains of the design world 11
Figure 3. 2 Preparation Flow 17
Figure 3. 3 Collecting Data Flow 18
Figure 3. 4 Processing Flow 19
Figure 4. 1 Uniformity test Grafic of DGmax Body dimensions 25
Figure 4. 2 Normality data test result 26
Figure 4. 3 Design of Comfortable Attribute 32
Figure 4. 4 Design of Ease of Cutting Attribute 32
Figure 4. 5 Design of Safety Attribute 33
Figure 4. 6 Design of Reliability Attribute 33
Figure 4. 7 Final Design concept based on axiomatic mapping 34
Figure 4. 8 Final Desain Concept salak harvesting tools 34

CHAPTER I
INTRODUCTION

1.1 Background

Salak or snake fruit (Salacca zalacca Gaertner Voss.) is one of Indonesia's important horticultural commodities with high economic value and broad market opportunities, both in domestic and export markets. Salak varieties are differentiated based on flesh texture, skin color, fruit size, aroma, taste, and plant growth characteristics (Syafriani et al., 2024). In Indonesia, salak cultivation is concentrated in several regions, with Sleman Regency in the Special Region of Yogyakarta recognized as one of the major production centers. Based on data from the Horticultural Statistics of Yogyakarta (2018), salak contributed the largest average annual production share among major fruit commodities, accounting for approximately 39.8% during the 2014 to 2018 period. This high level of production highlights the significant role of salak in supporting the regional agricultural economy.

Despite its high production level, the harvesting process of salak is still commonly performed using traditional and manual methods. According to Kinasih & Purnomo (2012), most salak agricultural activities, including pruning and harvesting, are carried out using simple tools such as knives and sickles. Based on direct interviews with salak farmers, the harvesting process is typically conducted manually without the use of specialized tools designed specifically for salak picking. The use of non-ergonomic tools often results in fruit damage during harvesting and contributes to physical discomfort and fatigue due to the heavy weight and inadequate sharpness of the tools used (Benos et al., 2020).

A more specific problem arises from the unique physical characteristics of the salak plant, which has sharp thorns surrounding the fruit clusters. During harvesting, farmers have to put their hands between thorny branches, which often causes injuries even though they use simple gloves. At the same time, the harvesting process also takes quite a long time, showing that the main problems come from the sharp salak thorns and the slow harvesting process (Suherman & Wibolo, 2015). This condition indicates the need for better protective and ergonomic solutions to minimize injury risks during harvesting activities.

Therefore, the development of an ergonomic salak harvesting tool is required to reduce injury risks and improve harvesting safety. This research applies Axiomatic Design

as the main method to develop functional and structural design parameters. Anthropometric data are used to determine ergonomic dimensions, while usability evaluation is conducted to measure the efficiency and user satisfaction of the proposed tool design.

1.2 Problem Formulation

Based on the existing problems, the research questions are formulated as follows:

1. What customer attributes are required by salak farmers in the development of an ergonomic salak harvesting tool?
2. What functional requirements and design parameters can be developed using Axiomatic Design to produce an ergonomic salak harvesting tool design?
3. What are the validation results and the level of user satisfaction achieved by the proposed salak harvesting tool design?

1.3 Research Objectives

Based on the research questions, the objectives of this study are:

1. To identify customer attributes required for the development of salak fruit harvesting picking tool to minimize injury risks during harvesting activities.
2. To determine functional requirements and design parameters using Axiomatic Design to design an ergonomic salak harvesting tool.
3. To validate the proposed harvesting tool design and to determine the level of user satisfaction.

1.4 Benefits of research

The benefits of this research will provide both practical and academic benefits. Practically, the proposed salak harvesting tool design is expected to improve safety, reduce injury risk from thorns, and enhance harvesting efficiency for salak farmers. Academically, this study contributes to the application of Axiomatic Design supported by anthropometric and usability approaches and can serve as a reference for future research in ergonomic agricultural tool design.

1.5 Research Limitations

To maintain the focus and feasibility of this study, the limitations of this study are defined as follows:

1. The research is limited to the design and development of a manual salak fruit harvesting tool and does not include mechanized or automated systems.
2. Evaluation of the tool is limited to ergonomic and functional performance assessments and does not include large-scale field implementation or economic feasibility analysis.
3. Anthropometric data used in this study are based on a specific group of salak farmers and may not fully represent all farmer populations.
4. The usability evaluation was limited to user subjective satisfaction with the proposed design and was conducted using a visual representation that doesn't involved advanced statistical or experimental methods.
5. The application of axiomatic design in this study is limited to the conceptual design stage and does not include further optimization or prototyping stage for the tools.

CHAPTER II
LITERATURE REVIEW

2.1 Empirical Review

2.1.1 Axiomatic Design in Design Development

Several previous studies have applied Axiomatic Design in product development to improve functionality and performance. Research from Adillah et al., (2023) integrated circular and smart design aspects, while Santos et al., (2021) improved the productivity and efficiency of a salt washing machine through functional redesign. Permana & Samodro (2026). translated customer needs into design parameters for an ice cream cooling box, and Li et al. (2022) applied axiomatic design in developing a hybrid electric tractor for better efficiency and environmental performance. However, most previous studies did not incorporate ergonomic aspects, anthropometric analysis, usability evaluation, or user safety considerations in the design process. Therefore, this research aims to develop an ergonomic salak harvesting tool by integrating axiomatic design with anthropometric and usability approaches to improve safety, comfort, and efficiency.

2.1.2 Ergonomics and Human Factor in Agricultural Tools

Previous studies have highlighted the importance of ergonomic and human factor approaches in tool and product development. Bonello et al. (2025) integrated Axiomatic Design and Kansei Engineering to develop human-centered workstations, but the study remained conceptual and was not focused on agricultural tools. Rahman et al. (2023) identified important agricultural design criteria such as safety, ease of use, and low physical effort, although their study lacked direct implementation on harvesting tools. Barani & Behbood (2023) emphasized participatory ergonomic design to improve safety and usability, while the research from Negi et al. (2025) applied anthropometric data to modify agricultural hand tools for better comfort and efficiency. Akbar et al. (2025) analyzed injury risks in oil palm harvesting and showed the need for ergonomic improvements to reduce workload. Seo et al. (2022) proposed ergonomic harvest basket modifications to reduce musculoskeletal risks, while Robet et al. (2022) combined Quality Function Deployment and anthropometry to redesign a harvesting tool with improved performance. However, most previous studies either lacked systematic design methods, usability evaluation, or direct application to salak harvesting tools. Therefore,

this research integrates axiomatic design, anthropometric analysis, and usability evaluation to develop a safer and more ergonomic salak harvesting tool.

2.1.3 Development of Harvesting Tools

Previous studies have explored the development of harvesting tools for agricultural commodities. According to Arif and Azmi (2019), their study developed a pineapple harvesting tool to improve posture and reduce direct hand contact, but without ergonomic or quantitative evaluation. Minaturrahim et al. (2022) analyzed a mango harvesting tool focusing on process efficiency, although ergonomic and safety aspects were not considered. Referring to Kinasih & Purnomo (2012), the study redesigned a salak harvesting sickle using Quality Function Deployment and successfully improved productivity while reducing fatigue and musculoskeletal complaints; however, the usability evaluation was still limited. Suherman & Wibolo (2015) and Diptaya et al. (2020) also developed salak harvesting tools to improve harvesting effectiveness, but the tools still had ergonomic and technical limitations. Based on these studies, the integration of ergonomic aspects, anthropometric analysis, usability evaluation, and systematic design methods in salak harvesting tool development remains limited. Therefore, this research proposes an ergonomic salak harvesting tool by integrating Axiomatic Design, anthropometric analysis, and usability evaluation.

Table 2. 1 Research Gap

No	Researchers	Harvesting Tools	Salak Farm	Ergonomic	Axiomatic Design	Usability
1	Adilah et al., (2023)				√	
2	Bonello et al., (2025)			√	√	
3	Santos et al., (2021)				√	
4	Permana & Samodro (2026)			√	√	
5	Rahman et al., (2023)	√		√		√
6	Barani & Behbood (2023)	√		√		
7	Negi et al., (2025)	√		√		
8	Li et al., (2022)				√	
9	Akbar et al., (2025)	√		√		
10	Seo et al., (2022)	√		√		
11	Arif & Azmi (2019)	√				
12	Minaturrahim et al., (2022)	√				
13	Robet et al., (2022)	√		√		
14	Kinasih & Purnomo (2012)	√	√			
15	Suherman & Wibolo (2015)	√	√			
16	Diptaya et al., (2020)	√	√			
17	M Aldo S	√	√	√	√	√

Previous studies have developed various harvesting tools and applied ergonomic approaches in agricultural contexts, including several studies specifically related to salak harvesting. However, existing salak harvesting tools are generally still simple, manually operated, and lack ergonomic considerations, which leads to discomfort and a high risk of injury due to salak thorns. In addition, studies applying Axiomatic Design are mostly limited to general product development and have not been integrated with ergonomic and usability aspects in agricultural tools. Furthermore, usability

evaluation is rarely conducted in the development of harvesting tools. Therefore, there is a research gap in integrating Axiomatic Design with anthropometric analysis and usability evaluation to develop a safe, ergonomic, and efficient salak harvesting tool.

2.2 Theoretical Basis

2.2.1 Ergonomic

Ergonomics comes from the Greek words ergon (work) and nomos (rules). Ergonomics is defined as the science, technology, and art of harmonizing tools, work methods, and the environment with human skills, abilities, and limitations to achieve healthy, safe, and comfortable working conditions, while ensuring maximum effectiveness and productivity. Proper ergonomics is essential in operations that involve people, taking into account their skills and job requirements. (Mustika & Sutajaya, 2016)

Referring to Jaffar et al. (2011), ergonomics is normally known to be related to humans and their jobs. On a larger scope, ergonomics examines human behavioral, psychological, and physiological capabilities and limitations. Professionals in the field of ergonomics normally will design new work environments or modify established work environments based on studies on human capabilities and limitation. The basic premise of ergonomics is that job demands should not exceed workers' capabilities and limitations to ensure that they would not be exposed to work stresses that can adversely affect safety and health as well as the company's productivity.

Therefore, the objective of an ergonomics program is to provide a safe and productive workplace for the worker’s comfort to fulfil the goals and objectives of the organization. The harmony between the work environment, the job, and the people involved in the work is necessary to prevent injuries and to improve productivity, efficiency, and comfort.

2.2.2 Product Design

Design is a process of analyzing, evaluating, improving, and organizing a task or system both physical and non-physical to achieve an optimal result in the future based on available information. The design process begins with creating a product concept or sketch, followed by planning the materials required for production. After that, the product enters the manufacturing stage, and production costs are estimated to determine the overall expenses involved in producing the product (Azmi et al., 2021).

In engineering, product design plays a very important role. Design is based on ideas and concepts related to needs, which lead to the creation of a product. The stages in product design engineering generally begin with the design stage, followed by development, refinement, manufacturing, and distribution (Hermayudi et al., 2021).

2.2.3 Characteristics of Salak Fruit

Salak plants are characterized by compound leaves arranged in a pinnate structure, with an overall length ranging from approximately 3 to 7 meters. The petiole, leaf sheath, and individual leaflets are densely covered with numerous long, slender spines, which serve as a protective feature for the plant. These spines typically exhibit a gray to blackish coloration. The leaflets themselves are lanceolate in shape, featuring pointed tips and measuring around 8 cm in width and up to 85 cm in length. Additionally, the lower surface of the leaflets appears whitish due to the presence of a waxy coating, which may help reduce water loss and protect the leaf surface (Christie & Lestari, 2020).

In terms of root morphology, salak plants possess a fibrous root system that develops within shallow to moderately deep soil layers. This type of root structure allows the plant to efficiently absorb nutrients and water from the upper soil horizon. However, the root penetration is relatively limited, typically reaching depths of only about 10 cm to 50 cm below the soil surface. This shallow rooting characteristic makes the plant more dependent on surface soil conditions and moisture availability (Fatimah, 2013).

CHAPTER III
RESEARCH METHODOLOGY

3.1 Research Object

The main object of this study is the harvesting tools for salak farmers. The designed harvesting tool must meet the needs and comfort of salak farmers as end users. This approach will ensure that the harvesting tools not only function efficiently but also provide a sense of comfort, satisfaction, and trust for the farmers to use them.

3.2 Research Sample and Population

The target population in this research is the salak farmers who are located in Turi District, Yogyakarta. In this study, the sample consists of 30 respondents of the farmers who represent the population, including both male and female farmers who have experience in harvesting or picking salak, ensuring that the data collected is relevant and reflects actual harvesting practices.

3.3 Research Data Types

The data types that are used in this research are primary and secondary data; here's the explanation of each data type:

3.3.1 Primary Data

Primary data is the data that will be collected directly from observations in the field, which is in salak farms.

a. Interview data results regarding all of the information related to the harvesting process especially in the picking process of salak fruit from the beginning until the last process.
b. Observation data results that were carried out by systematically observing and recording facts and phenomena encountered in the salak farms currently.
c. Anthropometric data which will be carried out by direct measurement of the body dimensions of the salak farmers
d. Usability Data

   Usability data are carried out using the SUS Questionnaire

3.3.2 Secondary Data

Data obtained from literature review and explanation of previous research that relates to salak farmers and harvesting tools or the process of designing harvesting tools.

3.4 Data Collecting Method

Below are the data collection methodsa that are used to gain the main data in this study:

3.4.1 Observation Method

The observation method is conducted to directly examine the salak harvesting process in the field. This method aims to identify the tools used, working postures, and problems experienced by farmers, particularly related to safety, comfort, and efficiency. The results of this observation provide an initial understanding of the existing conditions and support problem identification in this research.

3.4.2 Interview Method

The interview method is carried out through direct discussions with salak farmers to obtain in-depth information regarding their needs and challenges during harvesting activities. The interviews focus on identifying user requirement attributes such as safety, comfort, ease of use, and tool effectiveness. The collected data are used as the basis for defining user requirements in the design process.

3.4.3 Direct Measurement

Direct measurement is a data collection method conducted by measuring the data directly in the field. In this study, direct measurement was used to obtain anthropometric data from salak farmers related to the design of the salak harvesting tool. The measurement process was carried out directly on the respondents using measuring instruments such as a measuring tape.

3.4.4 Literature Study

This review is conducted by collecting information from journals, books, and previous studies related to salak harvesting, ergonomic tool design, anthropometry, usability, and Axiomatic Design. This method is used to support the theoretical foundation and methodology applied in this research.

3.5 Research Instrument

The research instrument is the tool that will be used during the research of this harvesting tool design, which will support this research. Several tools are included, such as:

1. Handphone

   A handphone will be used to capture, record, and tool for making a note while collecting data process taken directly on the field.

2. SolidWorks Apps

   SolidWorks application is used as the main tool for visualization and to create the final design concept of salak harvesting tools.

3. SPSS Software.

   This software is used to analyze the data collected from questionnaires and anthropometry data.

3.5 Data Processing and Analysis Method

The data collection methods applied in this research are explained as follows:

3.5.1 Axiomatic Design

Axiomatic design is a methodology of scientific and structured framework that can be applied to a design process. It works based on an analytical thinking process and a mathematical process without trial-and-error experiments. Its design model contains four domains: customer, functional, physical, and process (Adilah et al., 2023).

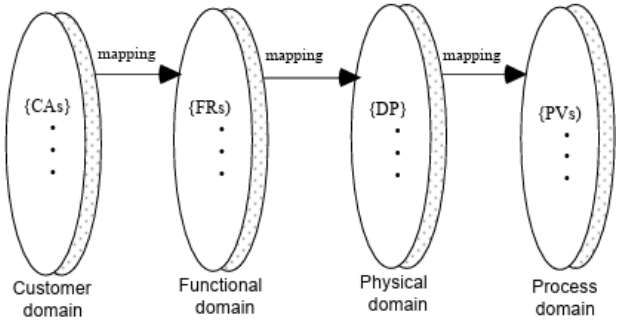


Figure 3.1 Four Domains of the design world

Source: (Suh, 2006)

Here are some points of the use of axiomatic design that will be used in this study:

1. Identifying User Needs

The first step is to identify user needs and preferences for the control panel interface design through a questionnaire. This process produces Customer Attributes (CA), which serve as key parameters for the redesign.

2. Mapping Customer Attributes (CA) to Functional Requirements (FR)
   After identifying the CA, the next step is to translate them into Functional Requirements (FR). FR describe the functions that the product must fulfill.
3. Mapping Functional Requirements (FR) to Design Parameters (DP)
   Next, the FR are translated into Design Parameters (DP), which explain how each required function will be achieved in the product design.
4. Translating Design Parameters (DP) into Process Variables (PV)
   The DP are then converted into Process Variables (PV). This step defines how the design will be implemented, particularly in the development of the salak harvesting tools.
5. Implementing the Process Domain (PV)
   The final step is to use the PV to guide how the interface will be physically created based on the predetermined physical domain. PV provide detailed direction for the salak harvesting tools.

3.5.2 Anthropometry

Anthropometry is a collection of numerical data related to the physical characteristics of the human body, including size, shape, and strength, as well as the application of this data to solve design problems. Anthropometry is widely used as an ergonomic consideration in the design process of products and work systems that involve human interaction. It is also a field of study that measures the human body based on anatomy, including body composition and physical dimensions across different nutritional levels and ages, with the aim of understanding human physical characteristics (Aras et al., 2019).

In this study, this approach aims to ensure that the tool design is ergonomic, comfortable, and safe to use, thereby reducing the risk of injury and physical fatigue during harvesting activities. Here are several steps that are used:

1. Data Collection

Anthropometric data are obtained from measurements of salak farmers, focusing on body dimensions relevant to tool usage, such as hand grip, reach, and arm movement.

2. Selection of Anthropometric Dimensions

   The selected dimensions include hand width, hand length, grip diameter, and arm reach. These parameters are used as the basis for determining the dimensions of the tool handle, grip design, and overall tool length.

3. Data Processing Using Percentiles

   The collected data are processed using percentile calculations to accommodate user variability:

   a. 5th percentile (P5): to ensure usability for users with smaller body dimensions
   b. 50th percentile (P50): as a reference for average dimensions
   c. 95th percentile (P95): to accommodate users with larger body dimensions

4. Application to Design Parameters

   The percentile values are applied to determine key design parameters, such as handle diameter, handle length, and reach distance, ensuring that the tool fits a wide range of users.

5. Design Validation

   The integration of anthropometric data into the design aims to improve comfort, reduce physical effort, and minimize the risk of musculoskeletal discomfort during harvesting activities.

3.5.3 Usability Testing

Usability testing evaluates how efficiently a system can be used, how easily it can be learned, and how well users can remember how to interact with it without difficulty. It mainly focuses on two key aspects, ease of learning, which measures the time required for users to understand and operate a new system compared to other methods, and ease of use, which assesses how efficiently tasks are completed, such as the number of actions needed to perform a task (Febrianti et al., 2019).

In this study, usability testing is conducted to evaluate how well the proposed salak harvesting tool can be used by users in terms of effectiveness, efficiency, and

satisfaction. This ensures that the design meets user needs and can be operated comfortably and safely. Use of System Usability Scale (SUS)

User satisfaction is measured using the System Usability Scale (SUS), which consists of 10 standardized statements with a Likert scale (1–5). Respondents are asked to rate their agreement with each statement regarding the proposed design.

3.5.4 Validity Test

The validity test is conducted to verify that an instrument is capable of measuring variables according to its intended purpose (Heale & Twycross, 2015). The purpose of the validity test is to evaluate the accuracy and appropriateness of questionnaire items so that the collected data can accurately represent the research variables. In this study, the validity test is used to ensure that each Customer Attribute (CA) and questionnaire item truly reflects the users' needs and evaluations regarding the designed salak harvesting tool.

3.5.5 Reliability Test

Reliability is an indicator that shows the extent to which a measuring instrument can be trusted and relied upon to produce consistent results when used repeatedly under similar conditions. This Reliability test also refers to the consistency and stability of a research instrument (Naga, 2004). One of the methods commonly used to measure reliability is the Cronbach's Alpha coefficient. An instrument is considered reliable if the Cronbach's Alpha value is greater than 0.70.

3.5.6 Uniformity Data Test

To ensure that the analyzed data is more valid and represents normal working conditions, a data uniformity test must be conducted before the data is used. By using a control chart, the data uniformity test helps identify data deviations that are either too small or too large. This method is designed to be simple and easy to understand to eliminate data that shows unusual or extreme deviations (Muchtar et al., 2024). The formula that used in this test is as follows:

Where:

- **UCL** = Upper control limit
- **LCL** = Lower control limit
- $\overline{X}$ = Mean value of the data
- σ = Standard deviation

- k = Confidence level constant
  - ❖ For a 99% confidence level, k = 3
  - ❖ For a 95% confidence level, k = 2
  - ❖ For a 68% confidence level, k = 1

To determine the standard deviation value, the following formula can be used:

$$\sigma = \sqrt{\frac{\sum(Xi - \bar{X})^2}{n-1}}$$

Where:

σ = Standard deviation

x = Data value

$\bar{X}$ = Mean value of the data

N = Number of data points

3.5.7 Normality Test

The normality test is a procedure used to determine whether the collected data originate from a population with a normal distribution pattern. A normal distribution is characterized by a symmetrical shape, where the mode, mean, and median are located at the center of the distribution (Sonjaya et al., 2025). The normal distribution is important in anthropometric data processing because calculations such as percentiles, mean values, and standard deviations generally rely on the assumption of normally distributed data.

The statistical hypotheses used in the normality test are as follows:

H0: The sample data are normally distributed.

H1: The sample data are not normally distributed.

3.5.8 Adequacy Data Test

The data adequacy test is used to determine whether the collected data are sufficient to be processed and analyzed further (Wasesa & Jumali, 2017). The data adequacy test is used to determine whether the number of samples collected is sufficient to represent the research population. This test is important to ensure that the anthropometric data obtained can produce an accurate and reliable design. The formula that is used in this test is as follows:

$$N' = \left[\frac{\frac{k}{s}\sqrt{(N.\Sigma x^2) - (\Sigma x)^2}}{\Sigma x} \right]$$

Where:

- N' = Required number of observations
- N = Total number of observations collected
- x = Observed data value
- k = Confidence level constant
- s = Desired level of accuracy
  - ❖ If the confidence level is 99%, then k = 2.58 = 3
  - ❖ If the confidence level is 95%, then k = 1.96 = 2
  - ❖ If the confidence level is 68%, then k = 1

The decision criteria for the data adequacy test are:

- If N' ≤ N, the collected data are considered adequate.
- If N' > N, additional data collection is required to achieve sufficient data adequacy.

3.5.9 Marginal Homogeneity Test

Marginal Homogeneity Test is a statistical test used to determine whether there are differences in marginal distributions between paired categorical or ordinal data, such as before and after measurements on the same respondents. This test is commonly used for matched-pair data and is an extension of the McNemar Test for variables with more than two categories (Shinoda et al., 2020).

3.5.10 Wilcoxon Signed-Rank Test

The Wilcoxon Signed-Rank Test is a non-parametric statistical test that serves the same purpose as the t-test to examine the difference in means between two datasets or two samples subjected to different treatments. This test also used to determine whether there is a significant difference between two paired datasets (Widiana et al., 2025).

3.6 Research Flow

This study involved three research stages: preparation, data collection and processing, and decision-making. The research process can be seen in the flowchart below:

3.6.1 Preparation Step

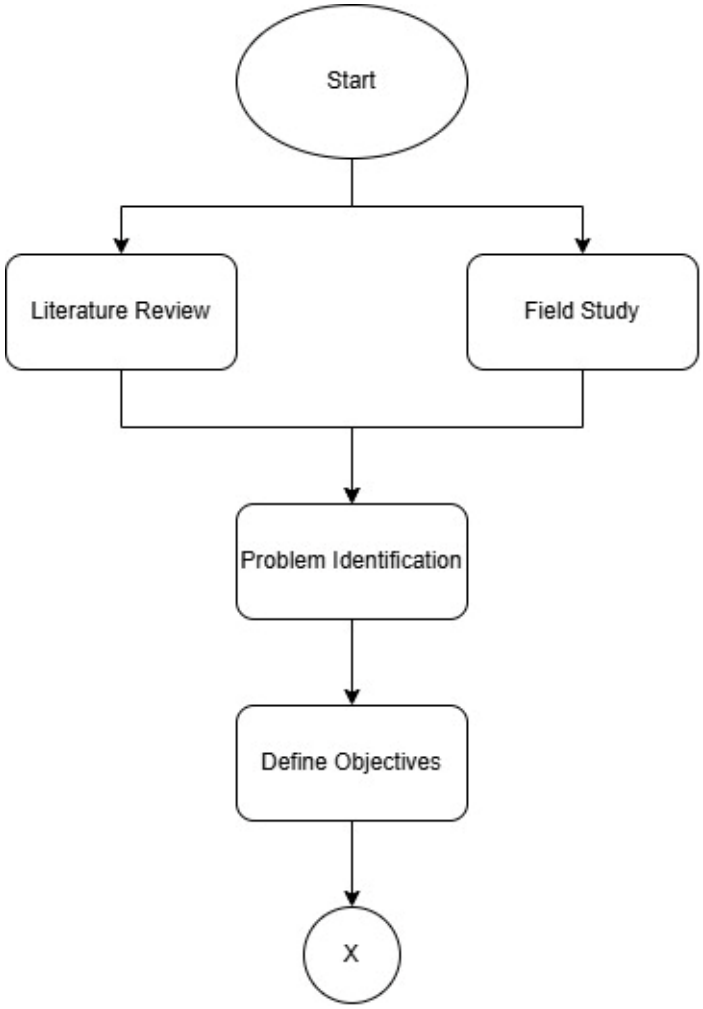


Figure 3. 2 Preparation Flow

The preparation stage begins with fieldwork and literature review on the topic to be researched, followed by identifying the existing problem. The next step is determining the objectives of the research.

3.6.2 Collecting Data

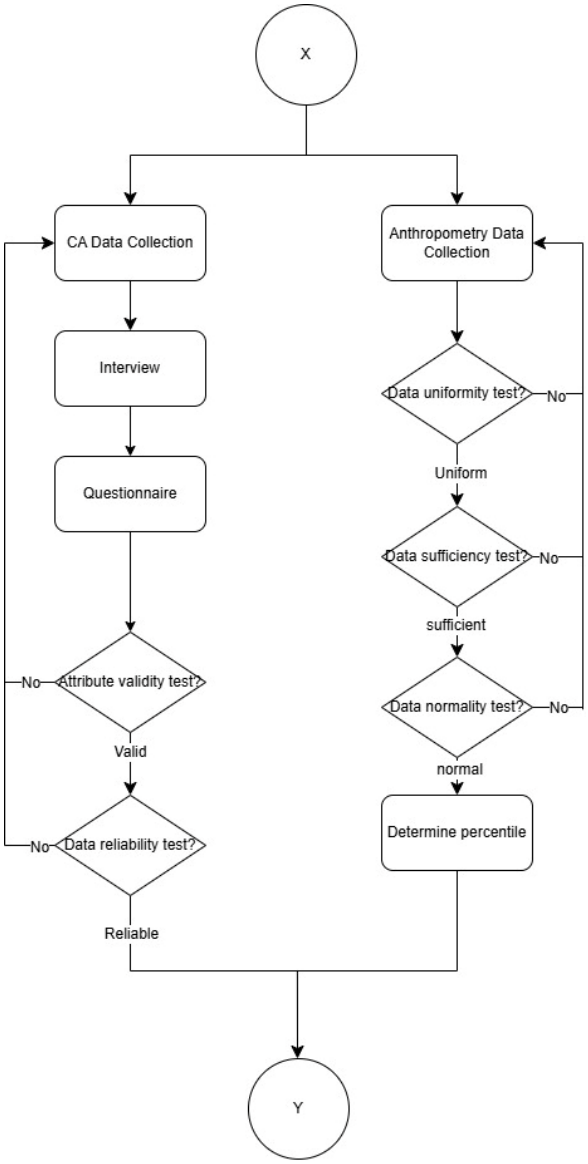


Figure 3. 3 Collecting Data Flow

The second stage is collecting customer attributes that become the main data that will be used in this study. The first step of collecting the customer needs is by using interview directly to the salak farmers as a respondent, then using a questionnaire to validate the customer needs from the farmers. Anthropometric data are also collected directly by measuring the body dimension of salak farmers. Once collected, a second questionnaire is distributed to test the validity and normality of the data. If any attributes fail the test, the data will be recollected, the same process applies to anthropometry data.

3.6.3 Processing Data

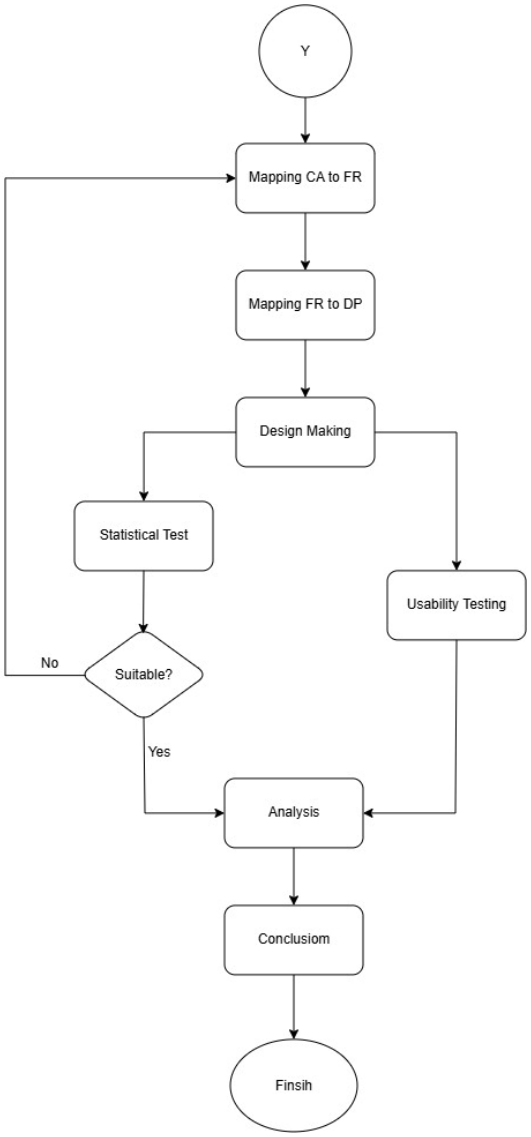


Figure 3. 4 Processing Flow

The identified customer attributes were subsequently translated into functional requirements and design parameters. Based on the results of the design parameter mapping, the proposed tool design was then developed. Following the design stage, a validation process was carried out to evaluate the proposed design. The validation was performed using statistical testing and usability evaluation, arranged in parallel, where the statistical tests assessed the proposed design based on the identified customer attributes, while the usability evaluation focused on user subjective satisfaction using SUS with the visual design concept.

CHAPTER IV
DATA COLLECTION AND PROCESSING

4.1 Data Collection

4.1.1 Respondent Characteristics

The respondents involved in this study were salak farmers located in Turi District who have direct experience in harvesting activities. The respondents were selected because they are actively involved in the salak harvesting process and are considered capable of providing relevant information regarding the problems and user needs related to the harvesting tools.

A total of respondents participated in this study is 30 people, consisting of both male and female farmers. The respondent characteristics analyzed in this research as follows:

Table 4. 1 Respondent characteristics

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	12	40
	Female	18	60
Age (Years)	< 20	0	0
	21–40	9	30
	> 41	21	70
Harvesting Experience (Years)	< 1	0	0
	1–5	0	0
	6–10	7	23,33
	> 10	23	76,67

These characteristics presents the demographic characteristics of the respondents involved in this study. The majority of respondents were female farmers (60%) and were over 40 years old (70%). In terms of harvesting experience, most respondents had more than 10 years of experience (76,67%). These characteristics suggest that the respondents possessed substantial practical knowledge and experience in salak harvesting, thereby providing reliable input for the ergonomic design and development of the harvesting tool.

4.2 Data Processing

4.2.1 Customer Attributes Identification

The first stage in the Axiomatic Design process involved the identification of Customer Attributes within the Customer Domain. Given the specialized characteristics of the respondents, namely experienced salak farmers actively involved in harvesting activities. Based on that, here's the customer attributes identifications table that already translated from customer needs:

Table 4. 2 CA Identifications

No	Customer Attributes	Code
1	Comfortable	CA1
2	Ease of Use	CA2
3	Safety	CA3
4	Reliability	CA4

The translation process was conducted to transform general user needs into more structured attributes that are relevant to the technical context of product design. The resulting Customer Attributes were then used as the main part for the Axiomatic Design Mapping process to determine the Functional Requirements and Design Parameters.

4.2.2 Validity Test

The validity test was conducted on all customer attributes obtained through the direct distribution of questionnaires to 30 salak farmers as the respondents of this study. The validity analysis was performed using IBM SPSS Statistics software to evaluate the ability of each questionnaire item to accurately represent the attribute being measured. The following is the results of validity test on the customer needs:

Table 4. 3 Result of Validity Test

No	Customer Needs	Corrected Item-Total Correlation	Description
1	Safe to Use	0.737	**Valid**
2	Reduce the Risks of Thorns Injuries	0.085	Not Valid
3	Comfortable to Use	0.648	**Valid**
4	Lightweight	0.523	**Valid**
5	Easy to Operate	0.650	**Valid**
6	Speeds Up the Harvesting Process	0.305	Not Valid
7	Ease to Reach	0.056	Not Valid
8	Minimize Fatigue	0.31	Not Valid

An item is considered valid if its Corrected Item-Total Correlation value exceeds the r-table value. In this study, a significance level of 5% was applied with a total of 30 respondents, resulting in an r-table value of 0.361. The Corrected Item-Total Correlation value of each item was then compared with the r-table value to determine the validity of each customer attribute.

4.2.3 Reliability Test

The reliability test was conducted to evaluate the consistency of the research instrument in measuring the intended attributes. Reliability analysis was performed using the Cronbach's Alpha method with the assistance of IBM SPSS Statistics software. An instrument is considered reliable if the resulting Cronbach's Alpha value meets the established criteria. The following table is the results of reliability test on the customer attributes:

Table 4. 4 Result of Reliability Test

Cronbach's Alpha	N of Items
0.816	**4**

Refers from Tavakol & Dennick (2011), the questionnaire was considered reliable when the Cronbach's Alpha value more than 0.70. The reliability test ensures that the questionnaire items provide consistent and dependable results in the data collection process.

4.2.4 Adequacy Test

A data adequacy test aims to determine whether the data collected in the study is sufficient to represent the population. The sample size is determined using the following formula:

$$N = \frac{Z^2 \, x \, p \, (1 \, - \, p)}{E^2}$$

Description:

Z = 1,645 (confidence level = 90%)

P = 0,1 (Assumed Population Proportion)

E = 0,10 (Margin of error)

Since the population proportion (p) is unknown, the author assumes a proportion (p) of 0.1, so the required sample size is as follows:

$$N = \frac{Z^2 \, x \, p \, (1 \, - \, p)}{E^2}$$

$$N = \frac{1{,}65^2 \, x \, 0{,}1 \, (1 \, - \, 0{,}1)}{0{,}10^2}$$

$$N = \, 24{,}5025$$

$$N = \, \mathbf{25}$$

In this study 30 respondents are taken for the data processing, with the objective is to identify user needs and establish design requirements, making an exploratory level of precision appropriate. According to Israel (2009), a 10% margin of error is acceptable for exploratory and preliminary studies. Research from Serdar et al., (2020) have reported that a margin of error ranging from 1% to 10% is generally considered acceptable, whereas values exceeding 10% are

not recommended. Therefore, a margin of error of 10% was selected as it remains within the acceptable range while providing a practical sample size for this exploratory study.

To complement this exploratory precision and ensure high data validity, the data collection is strictly conducted through face-to-face structured interviews using printed questionnaires. According to Griffin & Hausen (1993), they state that data saturation is proven to be reached within a sample of 10 to 30 users, since the salak farmers in Turi operate within a highly homogeneous working environment, data saturation is highly likely to be achieved within this sample size, making it statistically sufficient to map the Functional Requirements in the Axiomatic Design framework.

4.2.5Anthropometry Data Processing

4.2.5.1 Uniformity Testing Data

The data uniformity test was conducted to ensure that the anthropometric measurements collected from salak farmers were homogeneous and remained within acceptable statistical control limits. This test was used to identify and eliminate extreme data caused by measurement errors or abnormal physical conditions.

$$\sigma = \sqrt{\frac{\sum(Xi - \bar{X})^2}{n-1}}$$

The following is the results of the data uniformity test conducted on the four anthropometric dimensions used in this research:

$$\sigma = 0{,}15 \text{ (DGmax)}$$

$$\text{UCL} = \bar{X} + k.\sigma = 3{,}92 + 2.(0{,}173) = \mathbf{4,27}$$

$$\text{LCL} = \bar{X} - k.\sigma = 3{,}92 - 2.(0{,}173) = \mathbf{3,58}$$

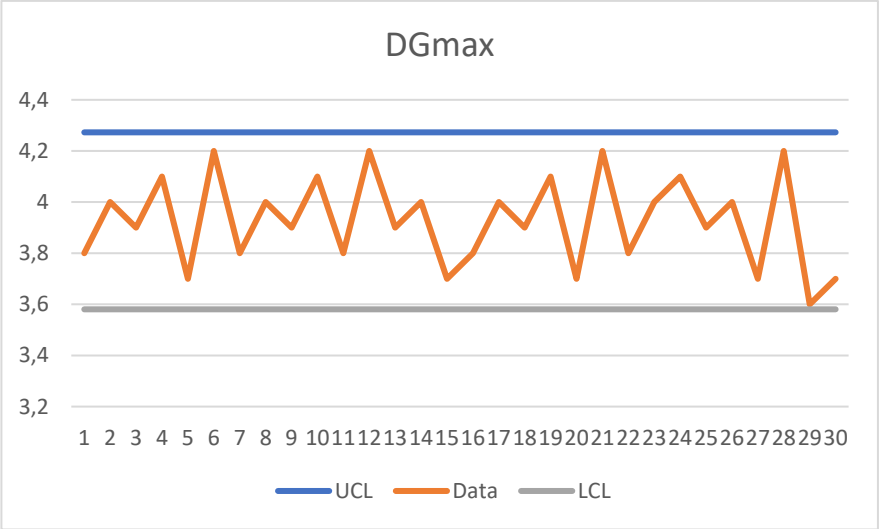


Figure 4. 1 Uniformity test Grafic of DGmax Body dimensions

Table 4. 5 Uniformity Testing Anthropometric Data

Body Dimension	Description
DGmax (Maximum Grip Diameter)	**Uniform**
LTM (Hand Breadth)	**Uniform**
PTT (Palm Length)	**Uniform**
PT (Hand Length)	**Uniform**

4.2.5.2 Adequacy Testing Data

The data adequacy test was carried out to determine whether the number of respondents involved in this study was sufficient to represent the target population. Considering the limited and specialized respondents involved, namely experienced salak farmers, the test used a 95% confidence level and 5% accuracy level.

$$N' = \left[\frac{\frac{k}{s}\sqrt{(N.\Sigma x^2) - (\Sigma x)^2}}{\Sigma x}\right]$$

If N' < N = data consider sufficient

The following is the results of the data adequacy test conducted on the four anthropometric dimensions used in this research:

$$N' = \left[\frac{\frac{2}{0{,}05}\sqrt{(30.13853{,}29) - (117{,}7)^2}}{117{,}7}\right]$$

$$N' = \mathbf{3{,}37} \text{ (DGmax)}$$

$$N' < N = \mathbf{3{,}37} < 30$$

Table 4. 6 Adequacy Testing Anthropometric Data

Body Dimension	N'	Description
DGmax (Maximum Grip Diameter)	3,373639042	**Sufficient**
LTM (Hand Breadth)	1,968723417	**Sufficient**
PTT (Palm Length)	0,761088721	**Sufficient**
PT (Hand Length)	1,45333318	**Sufficient**

4.2.5.3 Normality Testing Data

The data normality test was performed to determine whether the anthropometric data followed a normal distribution pattern. The following is the results of the normality data test conducted using SPSS Software on the anthropometric dimensions used in this research:

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
DGMax	.180	30	.014	.938	30	.080
LTM	.091	30	.200*	.941	30	.095
PTT	.102	30	.200*	.948	30	.150
PT	.121	30	.200*	.966	30	.444

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 4. 2 Normality data test result

4.2.5.4 Percentile Data

Percentile calculation was conducted to determine the anthropometric dimensions used as the basis for the ergonomic design of the salak harvesting tool. In anthropometric studies, percentile values are commonly used to accommodate variations in user body dimensions within the target population.

The following is the results of the percentile data conducted on the four anthropometric dimensions used in this research:

Table 4.7 Percentile Data

Body Dimension	Percentile					
	P5		P50		P95	
	Male	Female	Male	Female	Male	Female
Maximum Grip Diameter (DGMax)	3,62	**3,39**	3,91	3,83	4,28	4,21
Maximum Hand Width (LTM)	8,50	8,47	9	8,95	**9,49**	9,43
Palm Length (PTT)	10,56	9,83	11,43	10,36	**12,29**	10,90
Hand Length (PT)	16,71	**16,34**	17,51	17,21	18,31	18,06

4.3 Axiomatic Design Mapping Process

The mapping process for this axiomatic design start from CA identification, which the identified Customer Attributes (CAs) in this research were supported as well by previous ergonomic and agricultural tool studies. Comfortable (CA1) is important to reduce discomfort and physical fatigue during harvesting activities, as explained by Barani & Behbood (2023) who stated that ergonomic tools can improve comfort and productivity.

Ease of cutting (CA2) is required to focusing on improve cutting effectiveness and reduce harvesting effort, supported by Kinasih & Purnomo (2012) who found that sharper harvesting tools increased productivity and reduced fatigue. Safety Attributes (CA3) aims to minimize injury risks from salak thorns, which aligns with the studies of Akbar et al., (2025) regarding ergonomic improvements for injury prevention in agricultural work. Meanwhile, Reliability attribute (CA4) is necessary to reduce muscle strain and improve operational efficiency, as explained seo et al., (2022) in their ergonomic agricultural tool study. For more details, here's the tables of each CA that also translated into Functional Requirements (FR) and Design Parameter (DP):

Table 4. 8 Mapping result for CA1

Code	Customer Attribute	Code	Functional Requirement	Code	Design Parameter
CA 1	Comfortable	FR1	Prevent hand discomfort during harvesting operation	DP1	Ergonomic handle design
		FR1.1	Prevent unneutral wrist posture that leads to muscle fatigue and pain	DP1.1	Handle geometry
		FR1.1.1	Prevent excessive wrist flexion or extension during gripping	DP1.1.1	Handle with a 10-15 degrees curved angle
		FR1.1.2	Reduce localized pressure on the palm	DP1.1.2	Finger grooved design
		FR1.1.2.1	Provide an appropriate finger groove length	DP1.1.2.1	Percentile 95% LTM: 9,49cm
		FR1.2	Prevent grip slip during operation	DP1.2	Anti-slip handle design
		FR1.2.1	Prevent hand slippage during tool operation	DP1.2.1	Textured rubber coated handle surface
		FR1.2.1.1	Provide a stable thumb position for gripping	DP1.2.1.1	Contoured thumb groove handle design
		FR1.2.1.2	Provide an appropriate handle diameter for comfortable gripping	DP1.2.1.2	Percentile 5% DGmax: 3,39 cm

Code	Customer Attribute	Code	Functional Requirement	Code	Design Parameter
		FR1.2.1.3	Provide an appropriate handle length for comfortable gripping	DP1.2.1.3	Percentile 95% PTT: 12,29cm

Table 4. 9 Mapping result for CA2

	Customer Attribute	Code	Functional Requirement	Code	Design Parameter
CA 2	Ease of Cutting	FR2	Enable efficient cutting operation during harvesting	DP2	Mechanical cutting system
		FR2.1	Ensure effective stem cutting	DP2.1	High performance cutting blade
		FR2.1.1	Provide sufficient blade penetration into the fruit stem	DP2.1.1	Anvil type double bevel scissors
		FR2.1.2	Maintain cutting performance during repeated use	DP2.1.2	High carbon steel blade
		FR2.2	Reduce cutting effort during operation	DP2.2	Mechanical leverage system
		FR2.2.1	Reduce finger force required to actuate the cutting mechanism	DP2.2.1	Finger trigger mechanism
		FR2.2.1.1	Provide an appropriate trigger position for finger reach	DP2.2.1.1	Trigger position based on percentile 5% PT: 16,34 cm

	Customer Attribute	Code	Functional Requirement	Code	Design Parameter
		FR2.2.2	Transmit input force efficiently to the cutting blade	DP2.2.2	Internal steel linkage rod
		FR2.3	Facilitate fruit retrieval after cutting	DP2.3	Integrated fruit holder
		FR2.3.1	Secure the harvested fruit immediately after cutting	DP2.3.1	Square polypropylene mesh basket

Table 4. 10 Mapping result for CA3

Code	Customer Attribute	Code	Functional Requirement	Code	Design Parameter
CA 3	Safety	FR3	Minimize the risk of thorn injury during tool operation	DP3	Long Reach Cutting Attachment
		FR3.1	Isolate the operator's hands from the salak tree	DP3.1	Thorn Protection Extension Shaft Assembly
		FR3.1.1	Maintain a safe structural clearance between the grip handle and the cutting zone	DP3.1.1	Minimum handle to cutting zone distance = 50 cm

Table 4. 11 Mapping result for CA4

Code	Customer Attribute	Code	Functional Requirement	Code	Design Parameter
CA 4	Reliability	FR4	Maintain structural integrity during repeated harvesting operations	DP4	Lightweight aluminum structural frame
		FR4.1	Prevent structural deformation during harvesting	DP4.1	High strength aluminum alloy shaft
		FR4.1.1	Prevent shaft bending under operational load	DP4.1.1	Aluminum alloy tube with sufficient wall thickness
		FR4.2	Maintain handle integrity during repeated use	DP4.2	Impact resistant polymer handle housing
		FR4.2.1	Prevent handle cracking due to accidental impacts	DP4.2.1	Polypropylene (PP) handle material

4.4 Design Concept

The following pictures are the final concept design of salak harvesting tools based on customer attributes mapping, functional requirements, and design parameter.

4.4.1 Design based on Axiomatic mapping

The final design will be explain based on result of design parameters from each customer attributes. The following is the details:

1. CA 1 Comfortable:

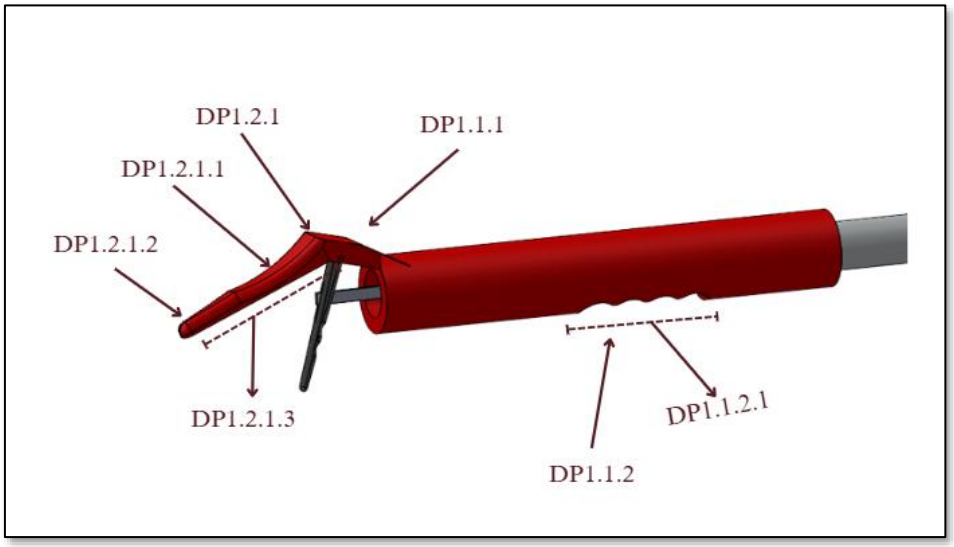


Figure 4. 3 Design of Comfortable Attribute

2. CA 2 Ease of Cutting:

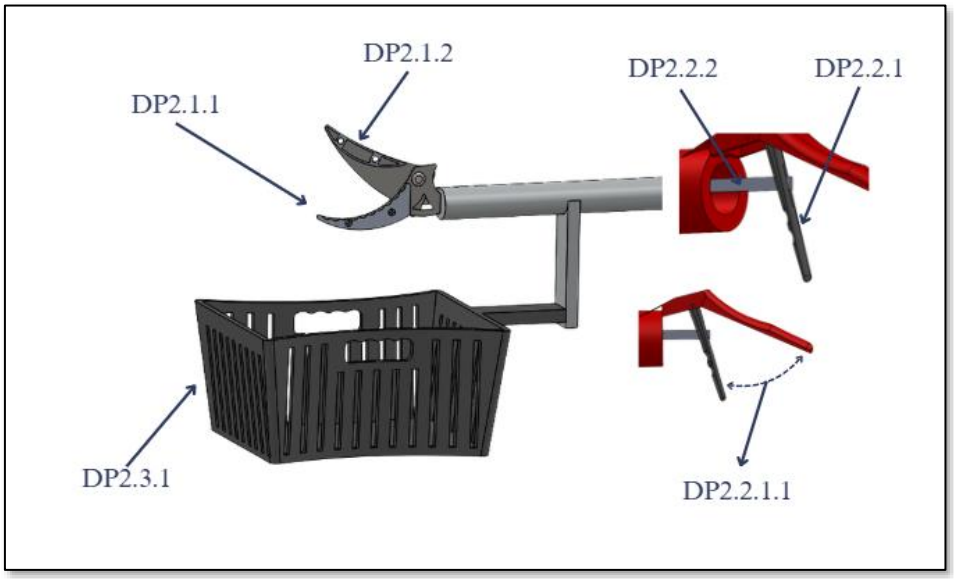


Figure 4. 4 Design of Ease of Cutting Attribute

3. CA 3 Safety:

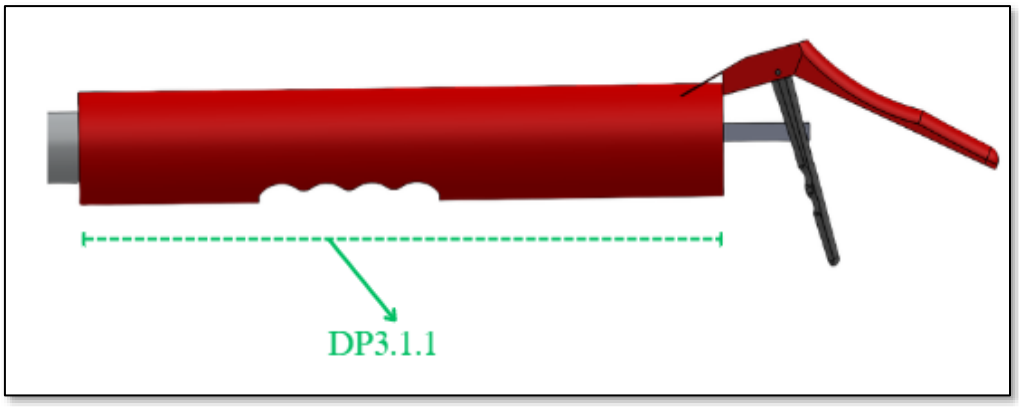


Figure 4. 5 Design of Safety Attribute

4. CA 4 Reliability:

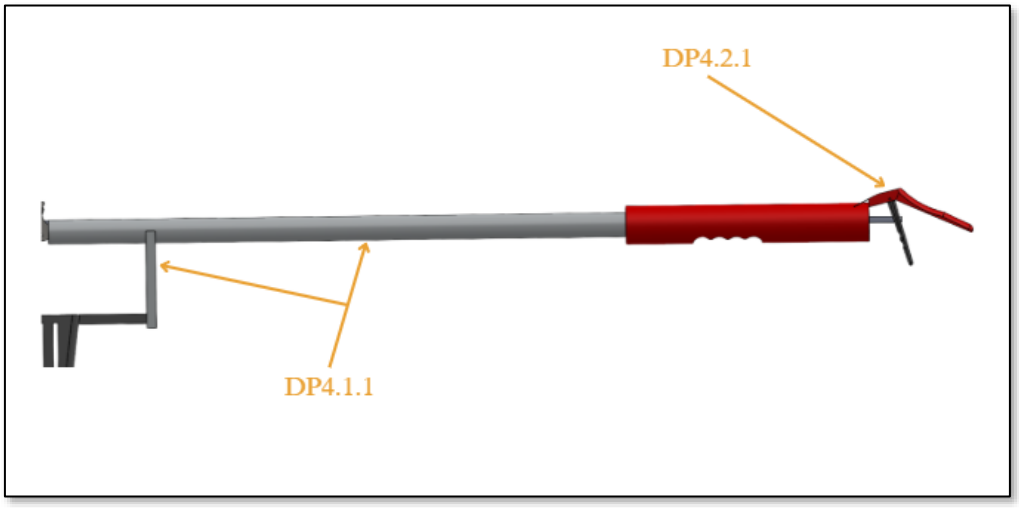


Figure 4. 6 Design of Reliability Attribute

4.4.2 Final Design Concept

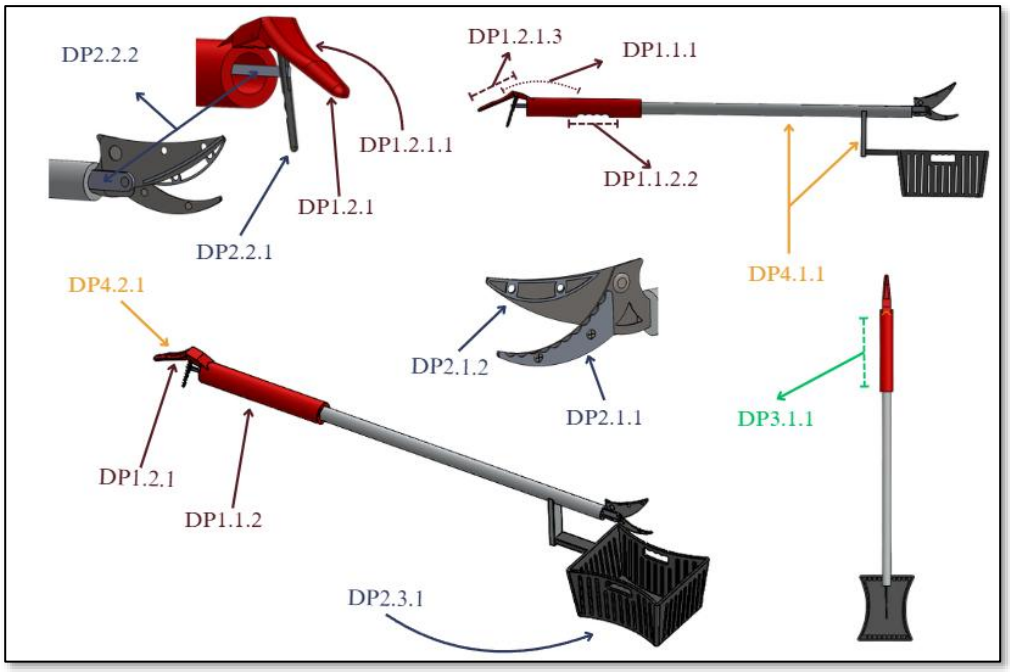


Figure 4. 7 Final Design concept based on axiomatic mapping

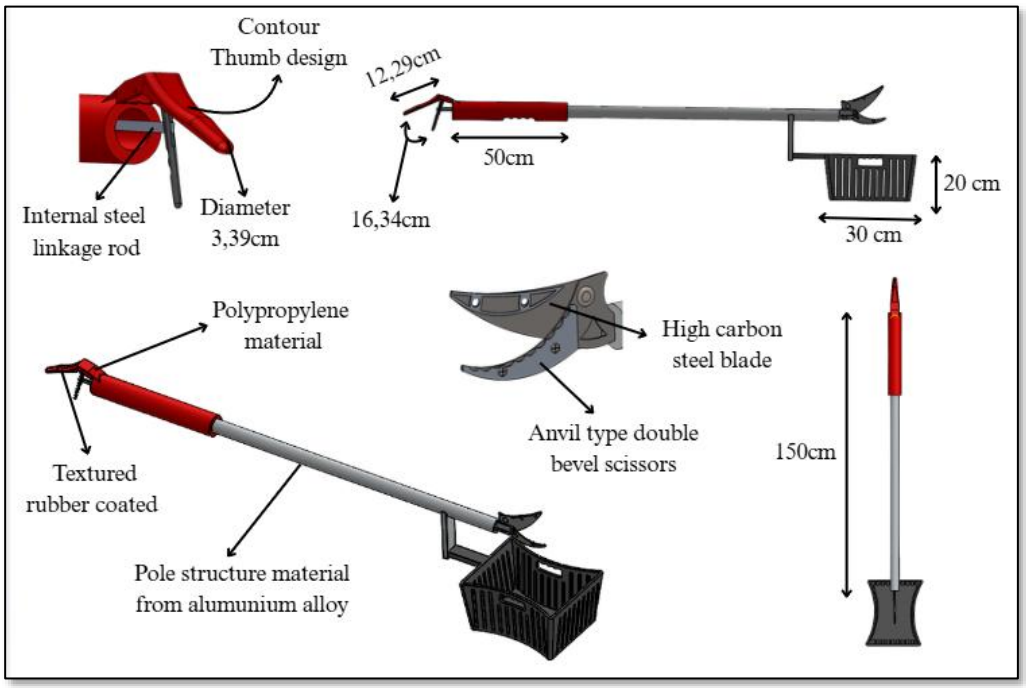


Figure 4. 8 Final Desain Concept salak harvesting tools

4.5 Proposed Design Validation

4.5.1 Marginal Homogeneity Test

The Marginal Homogeneity Test was conducted to determine whether the proposed salak harvesting tool design meets the customer attributes identified during the requirement analysis stage. This test compares the users' expectations with their evaluations of the proposed design concept to assess the level of conformity between user needs and the developed design. The hypotheses used in this study are as follows:

H0: There is no significant difference between the user needs and the proposed salak harvesting tool design.

H1: There is a significant difference between the user needs and the proposed salak harvesting tool design.

Table 4. 12 Result of Marginal Homogeneity Test

Customer Attribute	**Asymp. Sig. (2-tailed)**
Comfortable	0,058
Ease of Cutting	0,059
Safety	0,132
Reliability	0,221

The Marginal Homogeneity test result showed that all of the values of Asymp,Sig. (2-tailed) are greater than the significancy level of 5% (0.05), indicates that H0 is acceptable.

4.5.2 Wilcoxon Signed Rank Test

The Wilcoxon Signed-Rank Test is a non-parametric statistical test that serves the same purpose as the t-test to examine the difference in means between two datasets or two samples subjected to different treatments. In this study, the paired data consist of respondents' assessments of the existing salak harvesting tool and the proposed salak harvesting tool design based on the identified Customer Attributes, namely Comfortable, Ease of Cutting, Safety, and Reliability. The Wilcoxon Signed-Rank Test is appropriate for paired data because the same respondents provide assessments for both conditions. The hypotheses used in this study are as follows:

H0: There is no significant difference between customer attributes of the existing tool and the proposed tool design.

H1: There is a significant difference between customer attributes of the existing tool and the proposed tool design.

Using a significance level of 5% (0.05), the results of the Wilcoxon Signed Rank Test are presented as follows:

Table 4. 13 Result of Wilcoxon Test

Customer Attribute	**Asymp. Sig. (2-tailed)**
Comfortable	0,000
Ease of Cutting	0,001
Safety	0,001
Reliability	0,036

The Wilcoxon Signed-Rank Test results show significant differences between the existing and proposed designs for all Customer Attributes. Since all values are below 0.05, H0 is rejected, indicating significant differences between the existing and proposed designs.

4.5.2 Usability (Satisfaction)

Usability is an evaluation method used to determine the ease with which users interact with an information system, based on several indicators. In this study, the main focus of the usability testing is on the satisfaction aspects, which is to measure it the tools that used is SUS questionnaire. The following are the user satisfaction assessment results obtained via the System Usability Scale (SUS) questionnaire, presented in a table:

Table 4. 14 Result of SUS Test

SUS Score	**Grade**	**Adjective Rating**
75,75	B	Good

Based on the result above, the final SUS score shown that the average score is 75,75 with the grade category is B and the adjective rating is good, that can be said that the user is satisfy with the proposed design. Since this tool generally are used to evaluate user satisfaction of a system or product, the result indicating that the product falls into the "Acceptable" category and satisfy user perception.

CHAPTER V
DISCUSSION

5.1 Analysis of Customer Attributes

The following analysis explains about the needs of each attribute was based on the farmers' harvesting activities and requirements:

Comfortable (CA1) is required because harvesting activity involves repeated movement such as gripping, pulling, and cutting movements. When these activities are performed continuously, an inappropriate grip or hand position can increase discomfort and hand fatigue to the salak farmers. Therefore, farmers require a tool that can be held and operated comfortably for repeated harvesting activities. This need becomes a consideration for developing the handle geometry, grip surface, and handle dimensions.

Ease of Cutting (CA2) is required because cutting the salak stem is a critical part of the harvesting process. When the existing tool requires repeated cutting or sawing movements, the process can take more time and require greater physical effort. Therefore, farmers require a cutting mechanism that allows the stem to be cut more easily with fewer movements and less effort. This requirement becomes the basis for developing the proposed mechanical cutting and trigger mechanism.

Safety (CA3) is required because harvesting is performed around salak plants that have sharp thorns. The close distance between the farmer's hands and the plant increases the possibility of direct contact with the thorns and have potential to injury risk. Therefore, farmers require a tool that allows harvesting to be performed from a safer distance while maintaining control over the cutting process. This need is reflected in the development of the long-reach shaft and the separation between the handle and cutting area.

Reliability (CA4) is required because the harvesting tool is used repeatedly and must operate under field conditions. Farmers require a tool that does not easily bend, break, or lose its function during continuous use. A reliable tool can also reduce interruptions during harvesting and the need for frequent repairs or replacement. Therefore, structural strength, material selection, and resistance to physical impact become important considerations in the proposed design.

5.2 Analysis of Proposed Design

The following is the analysis of the result on functional requirements and design parameters based on Table 4.8 to 4.11 final axiomatic design mapping:

5.2.1 Analysis of Functional Requirements

Customer Attribute (CA1) is Comfortable, which represents the user's need for a comfortable hand interaction while gripping and operating the salak harvesting tool. The main Functional Requirement (FR1) is to prevent hand discomfort during harvesting operations, which focuses on minimizing discomfort experienced by the user's hand during tool operation. The functional requirements for the Comfortable attribute are presented in Table 4.8, covering FR1 through FR1.2.1.2.

Customer Attribute (CA2) is Ease of Cutting, which represents the user's need to perform the cutting and fruit retrieval processes with minimal difficulty during harvesting. The main Functional Requirement (FR2) is to enable efficient cutting operations during harvesting, focusing on improving the effectiveness and ease of the cutting process. The functional requirements for the Ease of Cutting attribute are presented in Table 4.9, covering FR2 through FR2.3.1.

Customer Attribute (CA3) is Safety, which represents the user's need to minimize the risk of injury caused by the sharp thorns of the salak plant during harvesting. The main Functional Requirement (FR3) is to minimize the risk of thorn-related injury during tool operation, emphasizing the separation of the user's hands from potentially hazardous areas of the plant. The functional requirements for the Safety attribute are presented in Table 4.10, covering FR3 through FR3.1.1.

Customer Attribute (CA4) is Reliability, which represents the user's need for the harvesting tool to maintain its structural strength and functionality throughout the harvesting process. The main Functional Requirement (FR4) is to maximize structural durability, focusing on maintaining the tool's structural performance during repeated use. The functional requirements for the Reliability attribute are presented in Table 4.11, covering FR4 through FR4.2.1.

5.2.2 Analysis of Design Parameters

The Design Parameters (DPs) for CA1 Comfortable are developed to support the prevention of hand discomfort during harvesting. DP1, an ergonomic handle design,

is implemented through several ergonomic features. DP1.1 uses an appropriate handle geometry, particularly a 10–15° curved handle angle (DP1.1.1), to support a more neutral wrist position during operation. The finger-grooved handle design (DP1.1.2), with a 95th percentile finger groove length of 9,49 cm (DP1.1.2.1), is applied to reduce localized palm pressure and accommodate the user's finger dimensions. For grip stability, DP1.2 provides an anti-slip handle design, implemented through a textured rubber-coated handle surface (DP1.2.1) to reduce hand slippage. The handle dimensions are also adjusted based on anthropometric data, with a 5th percentile DGmax of 3.39 cm (DP1.2.1.1) for the handle diameter and a 95th percentile PTT of 12,29 cm (DP1.2.1.2) for the handle length. These parameters are intended to provide an appropriate gripping size for the users.

The DPs for CA2 Ease of Cutting are designed to support efficient cutting with reduced operational effort. DP2, a mechanical cutting system, consists of DP2.1 high-performance cutting blade and DP2.2 mechanical leverage system. The cutting blade uses an anvil type double-bevel scissors (DP2.1.1) to provide effective penetration into the salak stem, while high carbon steel blade material (DP2.1.2) is selected to maintain cutting performance during repeated use. The reduction of cutting effort is supported by DP2.2, which incorporates a finger trigger mechanism (DP2.2.1) to allow the user to actuate the cutting mechanism, while an internal steel linkage rod (DP2.2.2) transfers the input force from the handle toward the cutting blade. The position of the finger trigger is further specified through DP2.2.1.1, with the trigger-to-handle distance determined based on the 95th percentile of PT, which is 16,34 cm to provide an appropriate finger reach during operation. In addition, DP2.3, an integrated fruit holder, is implemented using a square polypropylene mesh basket (DP2.3.1) to secure the harvested fruit immediately after cutting and facilitate fruit retrieval.

The DPs for CA3 Safety focus on separating the user's hands from the hazardous areas of the salak plant. DP3, a long-reach cutting attachment, provides an extended distance between the operator and the cutting area. This is supported by DP3.1, the thorn protection extension shaft assembly, which physically separates the operator's hands from the salak tree. Furthermore, DP3.1.1 specifies a minimum 50 cm distance between the handle and cutting zone to maintain structural clearance during

operation. This design parameter supports the FR of minimizing the risk of thorn injury while harvesting.

The DPs for CA4 Reliability are intended to maintain the structural integrity of the tool during repeated harvesting operations. DP4, a lightweight aluminum structural frame, provides the primary structural support while maintaining a relatively lightweight construction. DP4.1 uses a high-strength aluminum alloy shaft to prevent structural deformation during operation. More specifically, DP4.1.1 uses an aluminum alloy tube with sufficient wall thickness to prevent shaft bending under operational loads. For the handle, DP4.2 uses an impact-resistant polymer handle housing, with polypropylene (PP) material (DP4.2.1) selected to reduce the possibility of handle cracking caused by accidental impacts

5.3 Analysis of Proposed design validation

The following is the analysis of the proposed design from both validation or evaluations:

5.3.1 Marginal Homogeneity Test

The results from table 4.12 showed that the significant values of 0.058 for Comfortable CA1, 0.059 for Ease of Cutting CA2, 0.132 for Safety CA3, and 0.221 for Reliability CA 4. That can be conclude since all of the values is greater than 0.05, H0 acceptable, that's mean There is no significant difference between the user needs and the proposed salak harvesting tool design, this indicates that the proposed design already meets or suitable with the user need.

5.3.2 Wilcoxon Signed Rank Test

The results from table 4.13 showed significant value of 0.000 for Comfortable CA1, 0.001 for Ease of Cutting CA2, 0.001 for Safety CA3, and 0.036 for Reliability CA4. Since all values were below the significance level of 0.05, H0 was rejected. These results indicate that there are significant differences between customer attributes of the existing tool and the proposed tool design based from all four Customer Attributes. The higher assessment of the proposed design indicates that the developed tool provides improvements in comfort, cutting ease, safety, and reliability compared with the existing tool.

5.3.3 Usability (Satisfaction)

The usability evaluation was conducted using the System Usability Scale (SUS) to assess users' perceived usability and satisfaction toward the proposed salak harvesting tool. Refers from table 4.14, the evaluation resulted in an average SUS score of 75.75, corresponding to Grade B with an adjective rating of Good. This result indicates that the proposed harvesting tool provides an acceptable level of usability and a positive user experience. Therefore, the SUS evaluation demonstrates that the satisfaction aspect of the proposed tool is fulfilled, as users perceived the tool as usable and satisfactory for their harvesting operation.

CHAPTER VI
CONCLUSION AND SUGGESTIONS

6.1 Conclusion

Based on the results of the study on the development of an ergonomic salak harvesting tool, the following conclusions can be drawn:

1. The required customer attributes for the development of the ergonomic salak harvesting tool were identified through the Customer Attribute (CA) identification process. Four main attributes were established, namely Comfortable, Ease of Cutting, Safety, and Reliability.
2. The identified Customer Attributes were translated into Functional Requirements (FRs) and Design Parameters (DPs) using the Axiomatic Design approach. For CA1 Comfortable, the requirements were addressed through DP1.1.1 (10–15° curved handle), DP1.1.2 (finger-grooved handle), DP1.2.1 (textured rubber-coated surface), and anthropometric-based handle dimensions through DP1.2.1.1–DP1.2.1.2. For CA2 Ease of Cutting, the design incorporates DP2.1.1 (anvil-type double-bevel scissors), DP2.1.2 (high-carbon steel blade), DP2.2.1–DP2.2.2 (finger trigger and internal linkage rod), and DP2.3.1 (square polypropylene mesh basket) to facilitate cutting and fruit retrieval. For CA3 Safety, DP3.1 provides the thorn protection extension shaft assembly, supported by DP3.1.1, which maintains a minimum 50 cm distance between the handle and cutting zone. Meanwhile, CA4 Reliability is addressed through DP4.1.1, an aluminum alloy tube with sufficient wall thickness, and DP4.2.1, a polypropylene handle material, to maintain structural durability during operation.
3. The proposed harvesting tool achieved an average SUS score of 75.75, corresponding to Grade B with an adjective rating of Good, indicating an acceptable level of perceived usability and user satisfaction. The usability evaluation using the System Usability Scale (SUS) was conducted as a complementary assessment to obtain users' subjective perceptions of the proposed harvesting tool design. The evaluation of the proposed design was based on the visual representation and proposed concept. The Marginal Homogeneity test showed all values are greater than 0.05 with the detail 0.058 for CA1, 0.059 CA2,

0.132 CA3 and 0.221 for CA4, that indicates no significant difference between the user needs and the proposed salak harvesting tool design. Additionally, the Wilcoxon Signed-Rank Test also showed significant differences between the existing and proposed designs for all four Customer Attributes, with p value for all four customer attributes are below 0.05, which indicates there are significant differences between customer attributes of the existing tool and the proposed tool design based from all four Customer Attributes.

6.2 Suggestions

Based on the results of this research, several suggestions can be proposed for future development:

1. Future research is expected to continue the proposed design into a functional physical prototype and test it under actual harvesting conditions.
2. Future development should consider the manufacturing and development costs to ensure that the proposed tool is economically feasible for salak farmers.
3. Further improvements can be made based on the results of prototype testing and field evaluation to achieve better performance, ergonomics, safety, and reliability.
4. Further improvement expected adding some automation technology or other related systems.

REFERENCES

Adilah, M., Rau, H., & Procopio, K. M. (2023). Using an Axiomatic Design Approach to Develop a Product Innovation Process with Circular and Smart Design Aspects. *Using an Axiomatic Design Approach to Develop a Product Innovation Process with Circular and Smart Design Aspects*.

Akbar, A. R., Wibowo, A. D., & Asyikin, B. H. (2025). Risk Assessment for Long-Term Injury of Oil Palm Harvester. *Risk Assessment for Long-Term Injury of Oil Palm Harvester*.

Arif , M., & Azmi , M. (2019). Rancangan dan Pembuatan Alat Pemanen Buah Nenas . *Rancangan dan Pembuatan Alat Pemanen Buah Nenas* .

Azmi, Arif, M., & Ramadani, D. M. (2021). Perancangan Alat Pemanggang Menggunakan Pendekatan Antropometri. *Perancangan Alat Pemanggang Menggunakan Pendekatan Antropometri*.

Barani, M., & Behbood, H. (2023). The Hand-Tool Design Ergonomics Principles in Handicraft Workplaces: A Hybrid Approach of Ergonomics and Participatory Design. *The Hand-Tool Design Ergonomics Principles in Handicraft Workplaces: A Hybrid Approach of Ergonomics and Participatory Design*.

Benos, L., Tsaopoulos, D., & Bochtis, D. (2020). A Review on Ergonomics in Agriculture. Part I: Manual Operations. *A Review on Ergonomics in Agriculture. Part I: Manual Operations*.

Bonello, A., Brown, C. A., Francalanza, E., Gauci, M. V., & Refalo, P. (2025). A novel human-centred approach using Axiomatic Design and Kansei engineering for designing physically and cognitively safe human-robot collaborative workstations. *A novel human-centred approach using Axiomatic Design and Kansei engineering for designing physically and cognitively safe human-robot collaborative workstations*.

BPS. (2018). *STATISTIK HORTIKULTURA DAERAH ISTIMEWA YOGYAKARTA 2018 Horticulture Statistics of Daerah Istimewa Yogyakarta 2018* . Provinsi D.I.Yogyakarta : Badan Pusat Statistik.

BPS. (2019). *STATISTIK HORTIKULTURA DAERAH ISTIMEWA YOGYAKARTA 2019 Horticulture Statistics of Daerah Istimewa Yogyakarta 2019* . Provinsi D.I.Yogyakarta : Badan Pusat Statistik.

Christie, C. D., & Lestari, N. A. (2020). IDENTIFIKASI MORFOLOGI DAN KEKERABATAN SALAK DI JAWA TIMUR. *IDENTIFIKASI MORFOLOGI DAN KEKERABATAN SALAK DI JAWA TIMUR.*

Diptaya, D. B., Gunadnya, I. B., & Setiyo, Y. (2020). Rancang Bangun Alat Pemanen Buah Salak Sederhana. *Rancang Bangun Alat Pemanen Buah Salak Sederhana*.

Fatimah, S. (2013). ANALISIS MORFOLOGI DAN HUBUNGAN KEKERABATAN SEBELAS JENIS TANAMAN SALAK (Salacca zalacca (Gertner) Voss BANGKALAN. *ANALISIS MORFOLOGI DAN HUBUNGAN KEKERABATAN SEBELAS JENIS TANAMAN SALAK (Salacca zalacca (Gertner) Voss BANGKALAN*.

Griffin, A., & Hausen, J. R. (1993). The Voice of the Customer. *The Voice of the Customer*.

Hanafie, A., Haslindah, A., Suradi, S, I., & Fajar, M. (2022). PENERAPAN ANTROPOMETRI TERHADAP RANCANGAN ALAT PRESS JERAMI YANG ERGONOMIS. *PENERAPAN ANTROPOMETRI TERHADAP RANCANGAN ALAT PRESS JERAMI YANG ERGONOMIS*.

Haviz, M., Suryaman, R. A., & Tri, R. (2021). Fenomena Alih Fungsi Lahan : Apakah Tenaga Kerja dapat Berpindah dari Sektor Pertanian Ke Sektor Lain ? (Studi Kasus Kabupaten

Bekasi). *Fenomena Alih Fungsi Lahan : Apakah Tenaga Kerja dapat Berpindah dari Sektor Pertanian Ke Sektor Lain ? (Studi Kasus Kabupaten Bekasi)*.

Heale, R., & Twycross, A. (2015). Validity and reliability in quantitative studies. *Validity and reliability in quantitative studies*.

Hermayudi, Sujana, I., & Rahmahwati, R. (2021). RANCANG BANGUN MESIN PENCACAH SAMPAH ORGANIK MENGGUNAKAN METODE KANSEI ENGINEERING DAN PENDEKATAN ANTROPOMETRI. *RANCANG BANGUN MESIN PENCACAH SAMPAH ORGANIK MENGGUNAKAN METODE KANSEI ENGINEERING DAN PENDEKATAN ANTROPOMETRI*.

Hu, Y., & Yan, K. (2023). Convolutional Neural Network Models Combined with KanseiEngineering in Product Design. *Convolutional Neural Network Models Combined with KanseiEngineering in Product Design*.

Huang, W., Hu, P., Tsai, F. S., Liu, Y., & Huang, Y. (n.d.). Smart Sales Empower Small Farmers: An Integrated Matching Method between Suppliers and Consumers Based on the Information Axiom. *Smart Sales Empower Small Farmers: An Integrated Matching Method between Suppliers and Consumers Based on the Information Axiom*.

Israel, G. D. (2009). Determining Sample Size. *Determining Sample Size*.

Jaffar, N., Tharim, A. A., Kamar, I. M., & Lop, N. (2011). A Literature Review of Ergonomics Risk Factors in Construction Industry . *A Literature Review of Ergonomics Risk Factors in Construction Industry* .

Kinasih, N. S., & Purnomo, H. (2012). DESAIN SABIT PERKEBUNAN SALAK UNTUK MENINGKATKAN PRODUKTIVITAS . *DESAIN SABIT PERKEBUNAN SALAK UNTUK MENINGKATKAN PRODUKTIVITAS* .

Li, J., Wu, X., Zhang, X., Song, Z., & Li, W. (2022). Design of distributed hybrid electric tractor based on axiomatic design and Extenics. *Design of distributed hybrid electric tractor based on axiomatic design and Extenics*.

Lokman, A. M., & Nagamachi, M. (2009). Validation of Kansei Engineering Adoption in E-commerce Web Design. *Validation of Kansei Engineering Adoption in E-commerce Web Design*.

Minaturrahim, H., Afief, R., Firly, T. M., Maulana, S., Restianti, V., & Parwati, N. (2022). Analisis Perancangan Alat Pemetik Buah Mangga (LATIKMA). *Analisis Perancangan Alat Pemetik Buah Mangga (LATIKMA)*.

Muchtar, D., Dewanto, & Fajri, Y. (2024). MENENTUKAN WAKTU STANDAR PADA AKTIVITAS KERJA PRODUKSI SABLON MANUAL DI CV. DWIPUTRA IHWA. *MENENTUKAN WAKTU STANDAR PADA AKTIVITAS KERJA PRODUKSI SABLON MANUAL DI CV. DWIPUTRA IHWA*.

Mustika , P. W., & Sutajaya, I. M. (2016). ERGONOMI DALAM PEMBELAJARAN MENUNJANG PROFESIONALISME GURU DI ERA GLOBAL. *ERGONOMI DALAM PEMBELAJARAN MENUNJANG PROFESIONALISME GURU DI ERA GLOBAL*.

Naga, D. S. (2004). PERANAN INTERKORELASI BUTIR TERHADAPKOEFISIEN RELIABILITAS CRONBACH ALPEADAN KTII}ER-RICEARDSON. *PERANAN INTERKORELASI BUTIR TERHADAPKOEFISIEN RELIABILITAS CRONBACH ALPEADAN KTII}ER-RICEARDSON*.

Negi, B., Signh, J., Singh, T. P., & Kumar, A. K. (2025). Design modifications of agricultural hand tools based on anthropometric study for the farm workers of Uttarakhand, India. *Design modifications of agricultural hand tools based on anthropometric study for the farm workers of Uttarakhand, India*.

Nielsen, J., & Landauer, T. K. (1993). A Mathematical Model of the Finding of Usability Problems. *A Mathematical Model of the Finding of Usability Problems*.

Permana , A. A., Budiraharjo, K., & Setiadi, A. (2021). ANALISIS EFISIENSI SALURAN PEMASARAN KOMODITAS SALAK PONDOH DI DESA GIRIKERTO KECAMATAN TURI KABUPATEN SLEMAN YOGYAKARTA. *ANALISIS EFISIENSI SALURAN PEMASARAN KOMODITAS SALAK PONDOH DI DESA GIRIKERTO KECAMATAN TURI KABUPATEN SLEMAN YOGYAKARTA*.

Permana, M. P., & Samodro, G. (2026). Implementation of the Axiomatic Design Method in the Design of Cooling Boxes for the Distribution of Ice Cream. *Implementation of the Axiomatic Design Method in the Design of Cooling Boxes for the Distribution of Ice Cream*.

Prajoko, M. A., Santosa, A., & Juarini. (2019). ANALISIS OPTIMALISASI FAKTOR-FAKTOR PRODUKSI SALAK PONDOH DI KELOMPOK TANI "SI CANTIK" KECAMATAN TURI KABUPATEN SLEMAN. *ANALISIS OPTIMALISASI FAKTOR-FAKTOR PRODUKSI SALAK PONDOH DI KELOMPOK TANI "SI CANTIK" KECAMATAN TURI KABUPATEN SLEMAN*.

Pulakiang, A. R., Polii-Mandang, J. S., & Sompotan, S. (2017). BEBERAPA KARAKTER MORFOLOGIS TANAMAN SALAK (Salacca zalacca (Gaert) Voss) DI KAMPUNG BAWOLEU, KECAMATAN TAGULANDANG UTARA, KABUPATEN KEPULAUAN SIAU TAGULANDANG BIARO. *BEBERAPA KARAKTER MORFOLOGIS TANAMAN SALAK (Salacca zalacca (Gaert) Voss) DI KAMPUNG BAWOLEU, KECAMATAN TAGULANDANG UTARA, KABUPATEN KEPULAUAN SIAU TAGULANDANG BIARO*.

Rahman, T., Yassierli, & Widyanti, A. (2023). Design guidelines for sustainable utilization of agricultural appropriate technology: Enhancing human factors and user experience. *Design guidelines for sustainable utilization of agricultural appropriate technology: Enhancing human factors and user experience*.

Robet, Y., Prawatya, Y. E., & Prima, F. (2022). RANCANG BANGUN ALAT PANEN SARANG WALET MENGGUNAKAN METODE QUALITY FUNCTION DEPLOYMENT (QFD) DENGAN PENDEKATAN ANTROPOMETRI. *RANCANG BANGUN ALAT PANEN SARANG WALET MENGGUNAKAN METODE QUALITY FUNCTION DEPLOYMENT (QFD) DENGAN PENDEKATAN ANTROPOMETRI*.

Rosi, F., Hidayat, K., Firmansyah, R. A., & Rahman, A. (2024). Perbandingan Metode dalam Pengembangan Mesin Pemanen Padi. *Perbandingan Metode dalam Pengembangan Mesin Pemanen Padi*.

Sadraey, M. H. (2013). *AIRCRAFT DESIGN A Systems Engineering Approach.* Daniel Webster College, New Hampshire, USA: A John Wiley & Sons, Ltd., Publication.

Santos, A. G., Fradinho, J., Muorao, A., Martinho, A., Cavique, M., Vieira, G., & Coelho, A. G. (2021). Increasing the performance of a Salt Washing Machine through Axiomatic Design. *Increasing the performance of a Salt Washing Machine through Axiomatic Design*.

Seo, M., Kim, H., & Jung, W. (2022). Ergonomic Improvements to Agricultural Harvest Baskets to Reduce the Risk of Musculoskeletal Disorders among Farmers. *Ergonomic Improvements to Agricultural Harvest Baskets to Reduce the Risk of Musculoskeletal Disorders among Farmers*.

Serdar, C. C., Cihan, M., Yucel, D., & Serdar, M. A. (2020). Sample size, power and effect size revisited: simplified and practical approaches in pre-clinical, clinical and laboratory

studies. *Sample size, power and effect size revisited: simplified and practical approaches in pre-clinical, clinical and laboratory studies*.

Shinoda, S., Tahata, K., Tomizawa, S., & Yamamoto, K. (2020). Marginal Continuation odds Ratio Model and Decomposition of Marginal Homogeneity Model for Multi-way Contingency Tables. *Marginal Continuation odds Ratio Model and Decomposition of Marginal Homogeneity Model for Multi-way Contingency Tables*.

Siagian, W. M., & Tambunan, A. E. (2024). Perancangan Mesin Penggiling Jagung Menggunakan Metode Axiomatic House Of Quality (AHOQ). *Perancangan Mesin Penggiling Jagung Menggunakan Metode Axiomatic House Of Quality (AHOQ)*.

Soleman, A., & Kakerissa, A. L. (2018). PENGEMBANGAN KONSEP ALAT BANTU PEMETIK BUAH PALA (STUDI KASUS : PERKEBUNAN PALA NEGERI BOOI). *PENGEMBANGAN KONSEP ALAT BANTU PEMETIK BUAH PALA (STUDI KASUS : PERKEBUNAN PALA NEGERI BOOI)*.

Sonjaya, R. P., Alliya, F. R., Naufal, S., & Nursalman, M. (2025). Pengujian Prasyarat Analisis Data Nilai Kelas: Uji Normalitas dan Uji Homogenitas. *Pengujian Prasyarat Analisis Data Nilai Kelas: Uji Normalitas dan Uji Homogenitas*.

Suh, N. P. (2006). APPLICATION OF AXIOMATIC DESIGN TO ENGINEERING COLLABORATION AND NEGOTIATION. *APPLICATION OF AXIOMATIC DESIGN TO ENGINEERING COLLABORATION AND NEGOTIATION*.

Suherman, I. K., & Wibolo, A. (2015). RANCANG BANGUN ALAT BANTU PEMETIK BUAH SALAK. *RANCANG BANGUN ALAT BANTU PEMETIK BUAH SALAK*.

Susanto, A., & Sahroni, T. (2024). Mini Organic Waste Chopper Design with Ergonomic Techniques. *Mini Organic Waste Chopper Design with Ergonomic Techniques*.

Syafriani, Afiah, & Aprilla, N. (2024). PKM Petani Tanaman Salak Dalam Upaya Meningkatkan Daya Tahan TubuhMasyarakat di Desa Muara Danau Kabupaten Kampar. *PKM Petani Tanaman Salak Dalam Upaya Meningkatkan Daya Tahan TubuhMasyarakat di Desa Muara Danau Kabupaten Kampar*.

Syukron, A., & Kholil, M. (2014). *PENGANTAR TEKNIK INDUSTRI.* Yogyakarta: Graha Ilmu.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *Making sense of Cronbach's alpha*.

Wasesa, A. J., & Jumali, M. A. (2017). Anthropometry Application for Flexible Chair College. *Anthropometry Application for Flexible Chair College*.

Wibowo, R. A., & Soewardi, H. (2023). Reka Bentuk Alat Angkut Ergonomis Tanaman Hortikultura untuk Menurunkan Sindrom Musculoskeletal. *Reka Bentuk Alat Angkut Ergonomis Tanaman Hortikultura untuk Menurunkan Sindrom Musculoskeletal*.

APENDIX

A. Interview and Observation at Salak Farms





B. Questionnaires Draft

KUESIONER 1
IDENTIFIKASI KEBUTUHAN PENGGUNA

Assalamu'alaikum Warahmatullahi Wabarakatuh

Perkenalkan, saya Muhammad Aldo Septiyandi, mahasiswa Program Studi Teknik Industri Universitas Islam Indonesia. Saat ini saya sedang melakukan penelitian Tugas Akhir mengenai "**Konsep perancangan alat panen salak ergonomis yang bertujuan untuk mengurangi risiko cedera dan meningkatkan efisiensi kerja petani salak**".

Melalui kuesioner ini, saya berharap Bapak/Ibu/Saudara/i dapat memberikan pendapat dan pengalaman terkait aktivitas panen salak serta kebutuhan terhadap alat panen yang lebih aman dan nyaman digunakan. Seluruh data yang diberikan akan dijaga kerahasiaannya dan hanya digunakan untuk kepentingan penelitian akademik.

Atas kesediaan dan partisipasi Bapak/Ibu/Saudara/i, saya mengucapkan terima kasih.

1. DATA RESPONDEN
Petunjuk Pengisian

Silakan pilih jawaban yang sesuai dengan kondisi Anda dengan memberi tanda (✓) atau (X) pada pilihan yang tersedia.
1. Nama:

: ……..

2. Jenis Kelamin
   a. Laki-laki b. Perempuan

3. Usia
   a. < 20 tahun
   b. 21 – 30 tahun
   c. 31 – 40 tahun
   d. > 40 tahun

4. Pengalaman dalam memanen salak

a. < 1 tahun
b. 1 – 5 tahun
c. 6 – 10 tahun
d. > 10 tahun

5. Apakah Anda pernah mengalami cedera atau kesulitan saat memanen salak?
   a. Ya
   b. Tidak

6. Alat yang biasa digunakan saat panen salak
   - Tangan langsung
   - Sabit
   - Pisau
   - Alat lainnya: .....

2. IDENTIFIKASI KEBUTUHAN PENGGUNA

Petunjuk Pengisian

Pada bagian ini, silakan pilih kriteria alat panen salak yang menurut Anda penting dan dibutuhkan. Jawaban boleh lebih dari satu.

1. Kriteria apa yang Anda inginkan dari sebuah alat panen salak?

   - Aman digunakan
   - Mengurangi risiko terkena duri
   - Nyaman digunakan
   - Ringan digunakan
   - Mudah dioperasikan
   - Mempercepat proses panen
   - Mudah menjangkau buah
   - Mengurangi kelelahan kerja
   - Lainnya: .....

2. Keluhan apa yang paling sering Anda alami saat memanen salak?

   - Tangan terkena duri salak
   - Cepat merasa lelah
   - Nyeri pada tangan, bahu, atau punggung
   - Sulit menjangkau buah salak
   - Buah sering jatuh atau rusak saat dipanen
   - Proses panen memerlukan waktu lama
   - Lainnya: .....

TERIMA KASIH

Terima kasih atas waktu dan kesediaan Bapak/Ibu/Saudara/i dalam mengisi kuesioner ini. Jawaban yang diberikan sangat membantu dalam proses penelitian dan pengembangan alat panen salak yang lebih aman, nyaman, dan efisien bagi petani.

KUESIONER 2

VALIDASI ATRIBUT

1. DATA RESPONDEN

Petunjuk Pengisian

Silakan pilih jawaban yang sesuai dengan kondisi Anda dengan memberi tanda (✓) atau (X) pada pilihan yang tersedia.

1. Nama:

: ……..

2. Jenis Kelamin
   a. Laki-laki b. Perempuan

Penilaian Kriteria Alat Panen Salak

Petunjuk Pengisian

Berikan tanda centang (✓) pada salah satu jawaban sesuai dengan pendapat Anda terhadap pernyataan berikut.

Keterangan:
1 = Sangat Tidak Setuju
2 = Tidak Setuju
3 = Netral
4 = Setuju
5 = Sangat Setuju

No	Pernyataan	1	2	3	4	5
1	Alat panen salak harus aman digunakan saat proses panen					
2	Alat panen salak harus dapat mengurangi risiko terkena duri					
3	Alat panen salak harus nyaman digunakan					
4	Alat panen salak harus ringan saat digunakan					
5	Alat panen salak harus mudah dioperasikan					

No	Pernyataan	1	2	3	4	5
6	Alat panen salak harus dapat mempercepat proses panen					
7	Alat panen salak harus mudah menjangkau buah salak					
8	Alat panen salak harus dapat mengurangi kelelahan kerja					

KUESIONER 3
KESESUAIAN PRODUK DENGAN *CUSTOMER ATTRIBUTES*

Kuisioner Validasi desain usulan alat panen salak
Petunjuk Pengisian

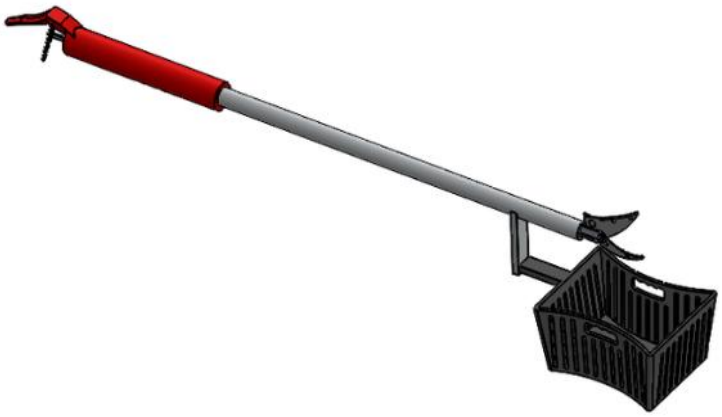
Berikut ini ditampilkan dua desain alat panen salak, yaitu desain eksisting yang saat ini digunakan oleh petani salak dan desain usulan hasil pengembangan menggunakan metode Axiomatic Design. Bagaimanakah pendapat anda tentang kesesuaian kedua produk ini dengan customer attribute?

	
Alat panen salak sebelum re-desain	Alat panen salak setelah re-desain

- **Comfortable (Kenyamanan)** – kenyamanan tangan saat menggenggam dan mengoperasikan alat.
- **Ease of Cutting (Kemudahan Pemotongan)** – kemudahan dalam melakukan pemotongan tangkai/batang buah salak dengan tenaga yang diperlukan.
- **Safety (Keamanan)** – kemampuan alat dalam mengurangi risiko tangan atau tubuh terkena duri pohon salak selama proses pemanenan.
- **Reliability (Keandalan)** – kemampuan alat untuk digunakan secara kuat, stabil, dan berulang selama proses pemanenan.

Data Responden

1. Nama:
   : ……..
2. Jenis Kelamin
   a. Laki-laki b. Perempuan

	
Alat panen salak sebelum re-desain	Alat panen salak setelah re-desain

Berikan tanda centang (✓) pada salah satu jawaban sesuai dengan pendapat Anda terhadap pernyataan berikut.

Keterangan:

1 = Sangat Tidak Setuju **2 = Tidak Setuju**
3 = Netral **4 = Setuju** **5 = Sangat Setuju**

No	Attribute	Desain Sebelum					Desain Sesudah				
		1	2	3	4	5	1	2	3	4	5
1	Comfortable (Kenyamanan)										
2	Ease of Cutting (Kemudahan Memotong)										
3	Safety (Keamanan)										
4	Reliable (Keandalan, Faktor alat Ringan dan kuat)										

Uji Usabilitas

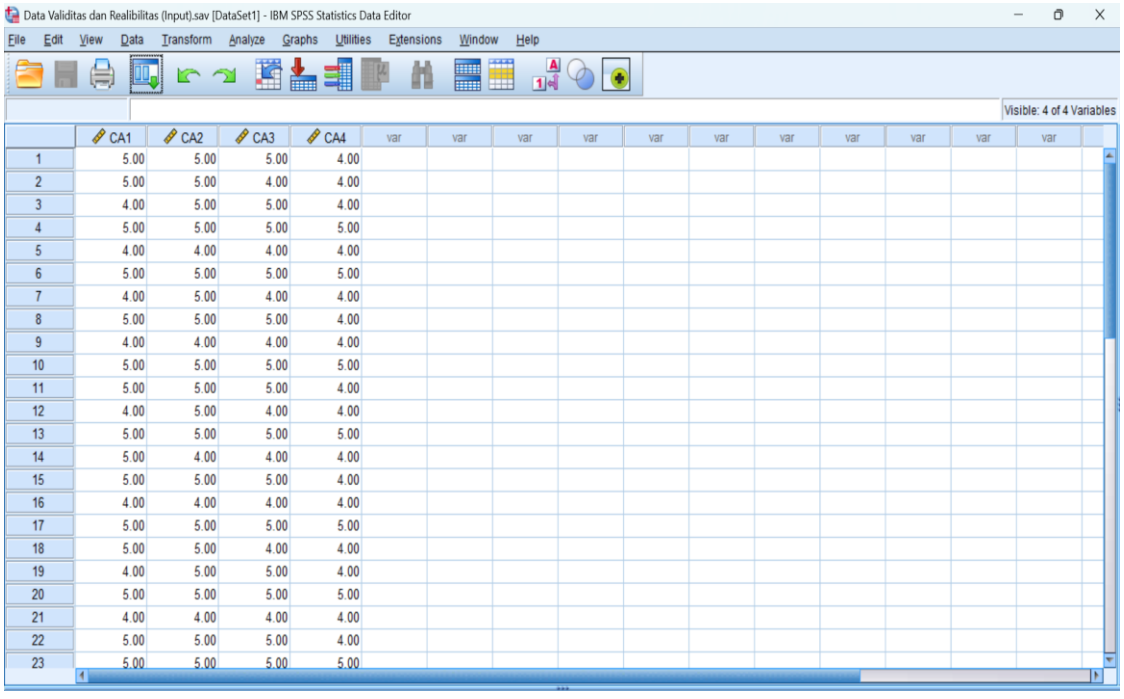
No	Pertanyaan SUS	Penilaian/Skor				
		1	2	3	4	5
1	Saya rasa saya akan sering menggunakan produk ini.					
2	Saya merasa produk ini rumit untuk digunakan.					
3	Saya merasa produk ini mudah untuk digunakan.					
4	Saya membutuhkan bantuan dari orang lain atau teknisi dalam menggunakan produk ini.					
5	Saya merasa berbagai fitur dalam produk ini berfungsi dengan baik.					
6	Saya merasa ada banyak ketidakkonsistenan (tidak serasi) dalam produk ini.					
7	Saya merasa orang lain akan rapidement (dengan cepat) memahami cara menggunakan produk ini.					
8	Saya merasa produk ini sangat membingungkan.					
9	Saya merasa tidak ada hambatan dalam menggunakan produk ini.					
10	Saya perlu membiasakan diri terlebih dahulu sebelum dapat menggunakan produk ini.					

C. Recapitulation Data

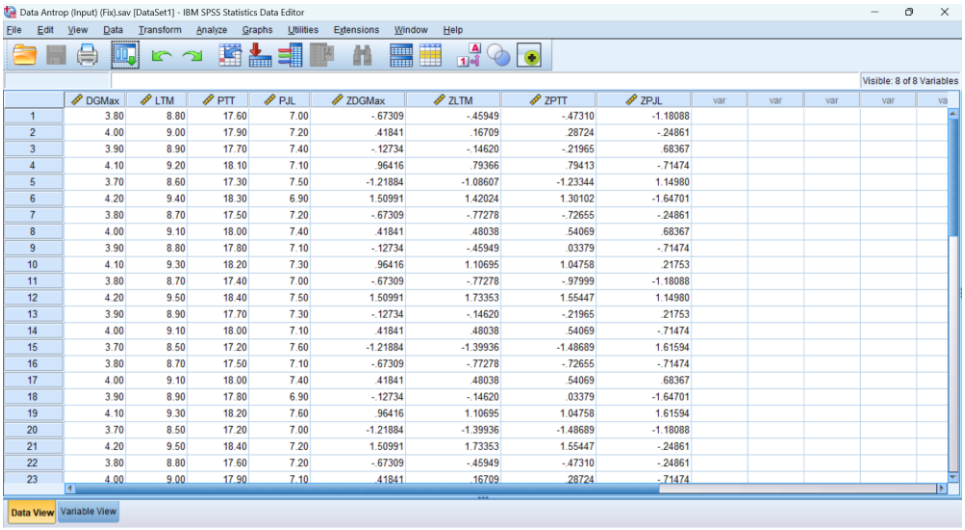
R	Customers Attributes
1	Aman Digunakan, Mengurangi Risiko terkena duri, Nyaman Digunakan, Mudah Dioperasikan, Alat Tajam
2	Aman Digunakan, Mengurangi Risiko terkena duri, nNyaman Digunakan, Ringan digunakan, Tajam
3	Nyaman, Ringan, Tidak Licin, Bahan Kuat, Tajam
4	Aman Digunakan, Mengurangi risiko terkena duri, Nyaman, Alat Tajam
5	Aman Digunakan, Nyaman Digunakan, Ringan, Tajam
6	Aman Digunakan, Mengurangi Risiko terkena duri, Nyaman digunakan, Tajam
7	Nyaman Digunakan, Ringan Digunakan, Tajam
8	Nyaman digunakan, Ringan digunakan, Mudah dioperasikan, Alat Tajam
9	Aman Digunakan, Nyaman Digunakan, Ringan, Tajam
10	Aman Digunakan, Mengurangi Risiko terkena duri, Nyaman Digunakan, Mudah Dioperasikan, Alat Tajam
11	Aman Digunakan, Nyaman Digunakan, Ringan Digunakan, Alat Tajam
12	Aman Digunakan, Nyaman Digunakan, Alat Tajam
13	Nyaman Digunakan, Ringan Digunakan, Alat Tajam
14	Aman Digunakan, Mengurangi Risiko terkena duri, Ringan Digunakan, Alat Tajam
15	Aman Digunakan, Nyaman Digunakan, Mengurangi Risiko terkena duri, Alat Tajam
16	Nyaman Digunakan, Ringan Digunakan, Mudah Dioperasikan, Alat Tajam

R	Customers Attributes
17	Aman Digunakan, Nyaman Digunakan, Ringan Digunakan
18	Aman Digunakan, Nyaman Digunakan, Alat Tajam
19	Nyaman Digunakan, Ringan Digunakan, Alat Tajam, Bahan Kuat
20	Aman Digunakan, Mengurangi Risiko terkena duri, Nyaman Digunakan, Ringan Digunakan, Alat Tajam
21	Aman Digunakan, Nyaman Digunakan, Alat Tajam
22	Aman Digunakan, Ringan Digunakan, Alat Tajam
23	Aman Digunakan, Nyaman Digunakan, Ringan Digunakan, Alat Tajam
24	Nyaman Digunakan, Mengurangi Risiko terkena duri, Alat Tajam
25	Aman Digunakan, Nyaman Digunakan, Mudah Dioperasikan, Alat Tajam
26	Aman Digunakan, Nyaman Digunakan, Ringan Digunakan, Bahan Kuat
27	Aman Digunakan, Mengurangi Risiko terkena duri, Nyaman Digunakan, Ringan Digunakan, Alat Tajam
28	Nyaman Digunakan, Ringan Digunakan, Alat Tajam
29	Aman Digunakan, Nyaman Digunakan, Ringan Digunakan, Alat Tajam
30	Aman Digunakan, Nyaman Digunakan, Mengurangi Risiko terkena duri, Alat Tajam

D. Data Processing



	CA1	CA2	CA3	CA4
1	5.00	5.00	5.00	4.00
2	5.00	5.00	4.00	4.00
3	4.00	5.00	5.00	4.00
4	5.00	5.00	5.00	5.00
5	4.00	4.00	4.00	4.00
6	5.00	5.00	5.00	5.00
7	4.00	5.00	4.00	4.00
8	5.00	5.00	5.00	4.00
9	4.00	4.00	4.00	4.00
10	5.00	5.00	5.00	5.00
11	5.00	5.00	5.00	4.00
12	4.00	5.00	4.00	4.00
13	5.00	5.00	5.00	5.00
14	5.00	4.00	4.00	4.00
15	5.00	5.00	5.00	4.00
16	4.00	4.00	4.00	4.00
17	5.00	5.00	5.00	5.00
18	5.00	5.00	4.00	4.00
19	4.00	5.00	5.00	4.00
20	5.00	5.00	5.00	5.00
21	4.00	4.00	4.00	4.00
22	5.00	5.00	5.00	4.00
23	5.00	5.00	5.00	5.00

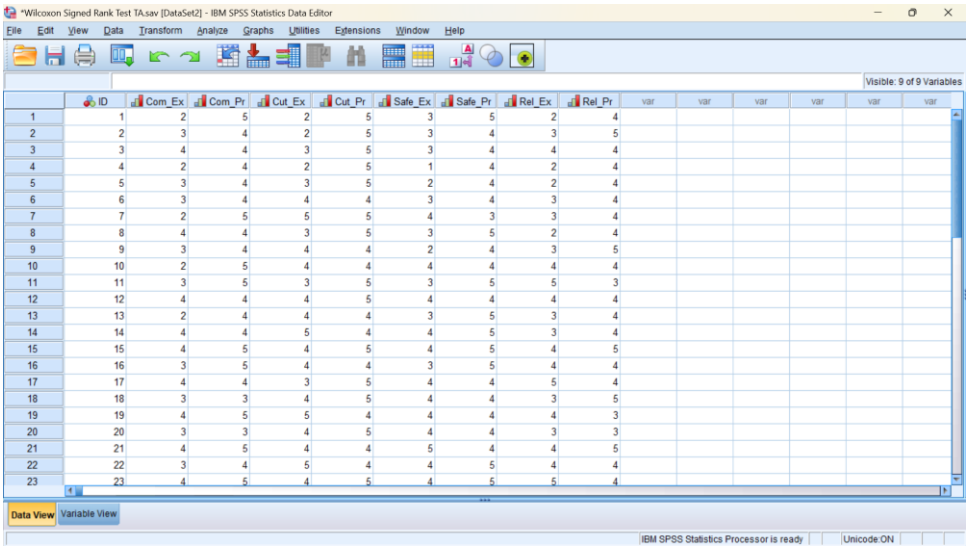

Data Antrop (Input) (Fix).sav [DataSet1] - IBM SPSS Statistics Data Editor

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Visible: 8 of 8 Variables

	DGMax	LTM	PTT	PJL	ZDGMax	ZLTM	ZPTT	ZPJL
1	3.80	8.80	17.60	7.00	-.67309	-.45949	-.47310	-1.18088
2	4.00	9.00	17.90	7.20	.41841	.16709	.28724	-.24861
3	3.90	8.90	17.70	7.40	-.12734	-.14620	-.21965	.68367
4	4.10	9.20	18.10	7.10	.96416	.79366	.79413	-.71474
5	3.70	8.60	17.30	7.50	-1.21884	-1.08607	-1.23344	1.14980
6	4.20	9.40	18.30	6.90	1.50991	1.42024	1.30102	-1.64701
7	3.80	8.70	17.50	7.20	-.67309	-.77278	-.72655	-.24861
8	4.00	9.10	18.00	7.40	.41841	.48038	.54069	.68367
9	3.90	8.80	17.80	7.10	-.12734	-.45949	.03379	-.71474
10	4.10	9.30	18.20	7.30	.96416	1.10695	1.04758	.21753
11	3.80	8.70	17.40	7.00	-.67309	-.77278	-.97999	-1.18088
12	4.20	9.50	18.40	7.50	1.50991	1.73353	1.55447	1.14980
13	3.90	8.90	17.70	7.30	-.12734	-.14620	-.21965	.21753
14	4.00	9.10	18.00	7.10	.41841	.48038	.54069	-.71474
15	3.70	8.50	17.20	7.60	-1.21884	-1.39936	-1.48689	1.61594
16	3.80	8.70	17.50	7.10	-.67309	-.77278	-.72655	-.71474
17	4.00	9.10	18.00	7.40	.41841	.48038	.54069	.68367
18	3.90	8.90	17.80	6.90	-.12734	-.14620	.03379	-1.64701
19	4.10	9.30	18.20	7.60	.96416	1.10695	1.04758	1.61594
20	3.70	8.50	17.20	7.00	-1.21884	-1.39936	-1.48689	-1.18088
21	4.20	9.50	18.40	7.20	1.50991	1.73353	1.55447	-.24861
22	3.80	8.80	17.60	7.20	-.67309	-.45949	-.47310	-.24861
23	4.00	9.00	17.90	7.10	.41841	.16709	.28724	-.71474

Data View | Variable View


*Wilcoxon Signed Rank Test TA.sav [DataSet2] - IBM SPSS Statistics Data Editor

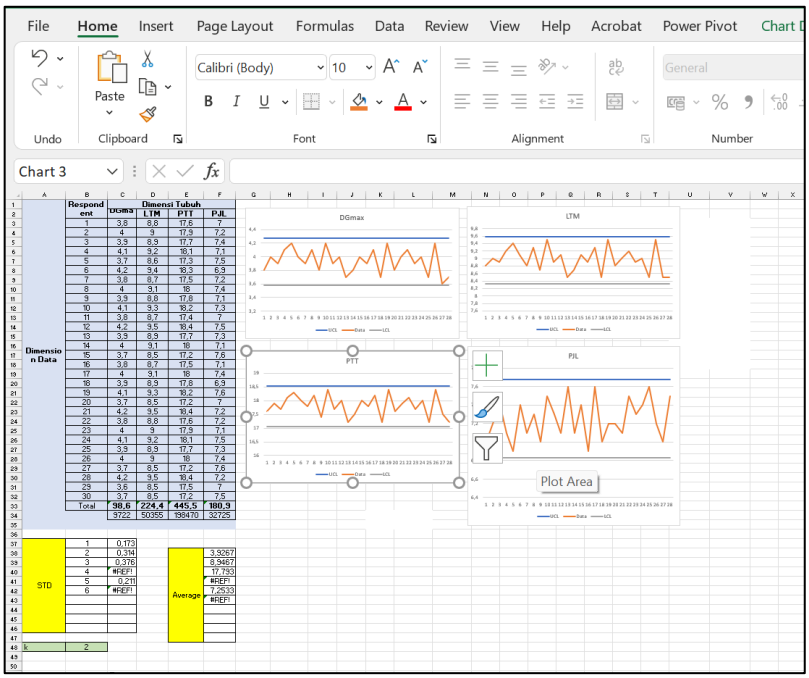
File Edit View Data Transform Analyze Graphs Utilities Extensions Window Help

Visible: 9 of 9 Variables

	ID	Com_Ex	Com_Pr	Cut_Ex	Cut_Pr	Safe_Ex	Safe_Pr	Rel_Ex	Rel_Pr
1	1	2	5	2	5	3	5	2	4
2	2	3	4	2	5	3	4	3	5
3	3	4	4	3	5	3	4	4	4
4	4	2	4	2	5	1	4	2	4
5	5	3	4	3	5	2	4	2	4
6	6	3	4	4	4	3	4	3	4
7	7	2	5	5	5	4	3	3	4
8	8	4	4	3	5	3	5	2	4
9	9	3	4	4	4	2	4	3	5
10	10	2	5	4	4	4	4	4	4
11	11	3	5	3	5	3	5	5	3
12	12	4	4	4	5	4	4	4	4
13	13	2	4	4	4	3	5	3	4
14	14	4	4	5	4	4	5	3	4
15	15	4	5	4	5	4	5	4	5
16	16	3	5	4	4	3	5	4	4
17	17	4	4	3	5	4	4	5	4
18	18	3	3	4	5	4	4	3	5
19	19	4	5	5	4	4	4	4	3
20	20	3	3	4	5	4	4	3	3
21	21	4	5	4	4	5	4	4	5
22	22	3	4	5	4	4	5	4	4
23	23	4	5	4	5	4	5	5	4

Data View | Variable View

IBM SPSS Statistics Processor is ready | Unicode:ON


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Chart 3

	Respondent	Dimensi Tubuh			
		DGMax	LTM	PTT	PJL
	1	3,8	8,8	17,6	7
	2	4	9	17,9	7,2
	3	3,9	8,9	17,7	7,4
	4	4,1	9,2	18,1	7,1
	5	3,7	8,6	17,3	7,5
	6	4,2	9,4	18,3	6,9
	7	3,8	8,7	17,5	7,2
	8	4	9,1	18	7,4
	9	3,9	8,8	17,8	7,1
	10	4,1	9,3	18,2	7,3
	11	3,8	8,7	17,4	7
	12	4,2	9,5	18,4	7,5
	13	3,9	8,9	17,7	7,3
Dimensio n Data	14	4	9,1	18	7,1
	15	3,7	8,5	17,2	7,6
	16	3,8	8,7	17,5	7,1
	17	4	9,1	18	7,4
	18	3,9	8,9	17,8	6,9
	19	4,1	9,3	18,2	7,6
	20	3,7	8,5	17,2	7
	21	4,2	9,5	18,4	7,2
	22	3,8	8,8	17,6	7,2
	23	4	9	17,9	7,1
	24	4,1	9,2	18,1	7,5
	25	3,9	8,9	17,7	7,3
	26	4	9	18	7,4
	27	3,7	8,5	17,2	7,6
	28	4,2	9,5	18,4	7,2
	29	3,6	8,5	17,5	7
	30	3,7	8,5	17,2	7,5
	Total	98,6	224,4	445,5	180,3
		3722	50355	198470	32725

STD	1	0,173
	2	0,374
	3	0,376
	4	#REF!
	5	0,211
	6	#REF!

Average	3,9267
	8,9467
	17,793
	#REF!
	7,2533
	#REF!

k 2

DGmax | LTM | PTT | PJL | Plot Area